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Global Inventory of Volatile Organic Compound Emissions from Anthropogenic Sources

Radian Corp., Research Triangle Park, NC

Prepared for:

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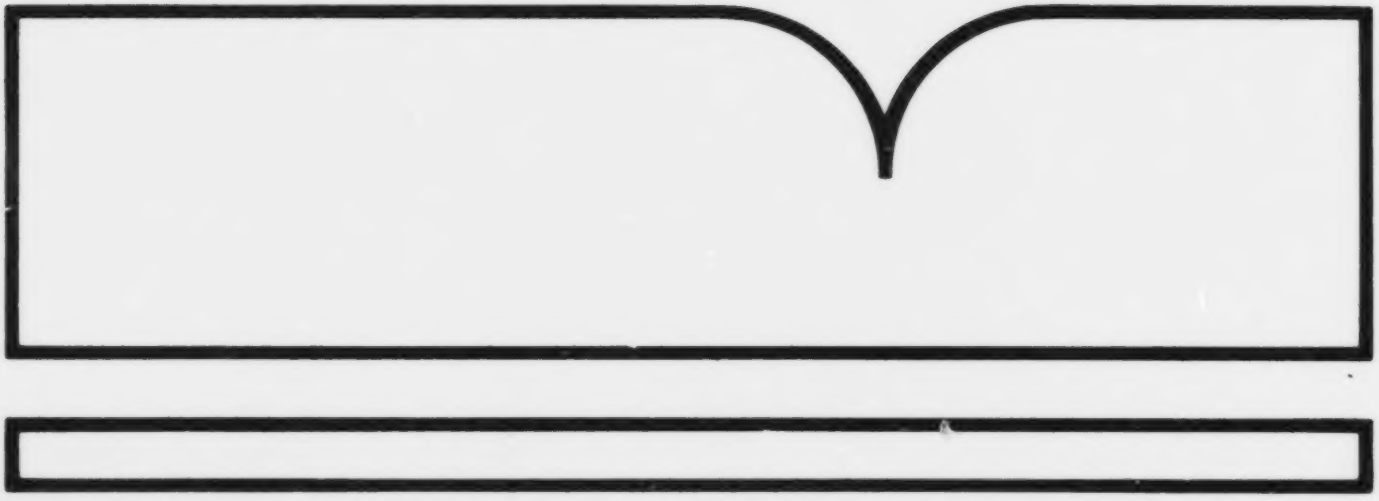

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GLOBAL INVENTORY OF
VOLATILE ORGANIC COMPOUND
EMISSIONS FROM
ANTHROPOGENIC SOURCES

Prepared for

Office of Policy, Planning, and Evaluation

Prepared by

Air and Energy Engineering Research
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16. ABSTRACT The report describes a global inventory of anthropogenic volatile organic compound (VOC) emissions that includes a separate inventory for each of seven pollutant groups--paraffins, olefins, aromatics, formaldehyde, other aldehydes, other aromatics, and marginally reactive compounds. The inventory, one input to atmospheric chemistry models required to estimate the global atmospheric concentration of ozone, is part of an assessment of the potential environmental impacts associated with global climate change. Study results show total global anthropogenic emissions of about 121 million short tons of VOCs per year. The U.S. is the largest emitter with 21% of the total. Globally, fuelwood combustion and savanna burning are the largest sources, together accounting for over 35% of global VOC emissions. The approach used to develop the inventory involved: (1) identifying the major anthropogenic sources of VOC emissions in the U.S. and grouping them into categories; (2) developing emission factors by dividing the U.S. emissions by the amount of production or consumption of the related commodity in the U.S.; (3) multiplying the U.S. emission factors by production/consumption statistics for other countries to yield global VOC emission estimates; and (4) geographically distributing the emissions.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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ABSTRACT

As part of an effort to assess the potential environmental impacts associated with global climate change, the U. S. Environmental Protection Agency is working with global atmospheric modelers to estimate the global atmospheric concentration of ozone. The atmospheric chemistry models require, as one input, an emissions inventory of reactive volatile organic compounds (VOCs). Consequently, a global inventory of anthropogenic VOC emissions has been developed. A separate inventory is presented for each of seven pollutant groups -- paraffins, olefins, aromatics [benzene, toluene, and xylene (BTX)], formaldehyde, other aldehydes, other aromatics, and marginally reactive compounds.

The technical approach used to develop this inventory involved four major steps. The first step was to identify the major anthropogenic sources of VOC emissions in the United States and to group these sources into categories. Source category selection was based on relating emissions to the production or consumption of a commodity. Emission factors were then developed by dividing the United States (U.S.) emissions by the amount of production or consumption of the related commodity within the United States. Multiplication of the U. S. emission factors by production/consumption statistics for other countries yielded global VOC emission estimates. The final step in development of the VOC inventory was geographic distribution of the emissions. Detailed maps of population and industrial activity were used in this distribution.

The results of this study show total global anthropogenic emissions of about 121 million tons of VOC per year. The United States is the largest emitter with 21 percent of the total. Globally, fuelwood combustion and savanna burning are the largest sources, together accounting for over 35 percent of global VOC emissions. All emission estimates are given in short tons per year (one short ton = 0.9072 metric ton).

CONTENTS

Abstract iii

Figures vi

Tables vi

1. Background and Scope 1

Overview of Technical Approach 2

Caveats 4

2. Technical Approach 5

Development of Groups of VOC Sources 5

Identification and Geographic Distribution of the Global Activity Data Associated with Each VOC Group 7

Grouping Individual VOC Species into Specific Classes and Development of VOC Class-Specific Emission Factors 20

3. Discussion of Uncertainties 26

Uncertainties in the Raw Data Used to Develop the Inventory 26

Uncertainties in the Interpretation of the Data 31

Uncertainties Associated with the Use of the Inventory 32

4. Summary of Results 34

References 52

Appendix: Global VOC Inventory -- Emissions Allocated to 10° X 10° Grid Cells 54

FIGURES

Number

1 Technical Approach Used in Developing Global VOC Emission Inventory . 3

2 Geographic Distribution of Emissions of Paraffins 42

3 Geographic Distribution of Emissions of Olefins 43

4 Geographic Distribution of Emissions of Aromatics 44

5 Geographic Distribution of Emissions of Formaldehyde 45

6 Geographic Distribution of Emissions of Other Aldehydes 46

7 Geographic Distribution of Emissions of Other Aromatics 47

8 Geographic Distribution of Emissions of Marginally Reactive Compounds 48

9 Geographic Distribution of Total VOC Emissions 49

TABLES

Number

1 Source Groups Included in the Global VOC Inventory 8

2 Global Activity Data Used To Estimate VOC Emissions From Each Source Group 11

3 Geographic Mapping Factor Used to Allocate Country-Specific Activity Data Into 10 By 10 Degree Grid Cells 17

4 VOC Speciation Profile Rating Definitions 27

5 Weighted Average Quality Ratings for the VOC Profiles Used for Selected Significant Sources 29

6 Global Controlled VOC Emissions by Country 35

7 Global Controlled Emissions by Category 40

SECTION 1

INTRODUCTION

1.1 BACKGROUND AND SCOPE

Increased atmospheric concentrations of carbon dioxide and other relatively important trace gases (e.g., methane, nitrous oxide, ozone, and chlorofluorocarbons) have raised concerns about potential climate change among the general public and members of the scientific community. However, there is much uncertainty remaining in the science involved in estimating global climate change. One of the areas of greatest uncertainty is the role of atmospheric chemical reactions, including those resulting in the formation of ozone (O_3). Key factors in these reactions are the atmospheric concentrations of volatile organic compounds (VOCs) and oxides of nitrogen (NO_x). Consequently, it is important to have emissions inventories for these gases with sufficient geographic resolution, and, for the VOCs, sufficient speciation into different reactivity classes, so that O_3 concentrations in the atmosphere can be estimated.

The purpose of this research effort was to develop a global emissions inventory of VOCs emitted from anthropogenic sources. The effort was conducted under the technical direction of EPA's Air and Energy Engineering Research Laboratory (AEERL) at the request of the Office of Policy, Planning, and Evaluation (OPPE). OPPE plans to use this inventory in atmospheric chemistry models developed by I.S.A. Isaksen at the University of Oslo, in Norway. His two-dimensional model requires VOC data, speciated in the following five reactivity classes:

Class 1 - Paraffins
Class 2 - Olefins
Class 3 - Aromatics

Class 4 - Formaldehyde
Class 5 - Other Aldehydes

Two other classes:

Class 6 - Other Aromatics
Class 7 - Marginally Reactive Compounds

were included in the inventory for the sake of completeness and to ensure that the needs of other atmospheric chemistry models for geographically gridded and speciated VOC data could be accommodated. The inventory was geographically resolved within 10 by 10 degree grids.

1.2 OVERVIEW OF TECHNICAL APPROACH

Figure 1 outlines the technical approach used to develop the global VOC inventory. This approach is described in detail in Section 2, below. The first step was to identify the major sources of VOC emissions in the United States (U.S.) and group the sources according to the type of commodities with which they are associated. For example, oil refinery heaters, catalytic cracking, and pipeline leaks represent a diverse group of VOC emission sources which are all related to crude oil. It is possible, therefore, to combine these U.S. sources and develop a relationship which describes their emissions as a function of the amount of crude oil processed in the U.S. Hereafter, groups of similar emission sources are referred to as source categories.

For each source category, the U.S. VOC emission estimates were divided by their associated commodity values. The resulting commodity-related emission factors, when multiplied by commodities statistics for other countries, yielded VOC emission estimates for those countries. For each category, as many as seven separate emission factors were developed to represent the seven VOC reaction classes listed above. Many sources emit all seven reaction classes of pollutants, while other sources emit only one or two.

Concurrent with the assignment of source categories, many references were consulted in order to gather the necessary global commodities data.

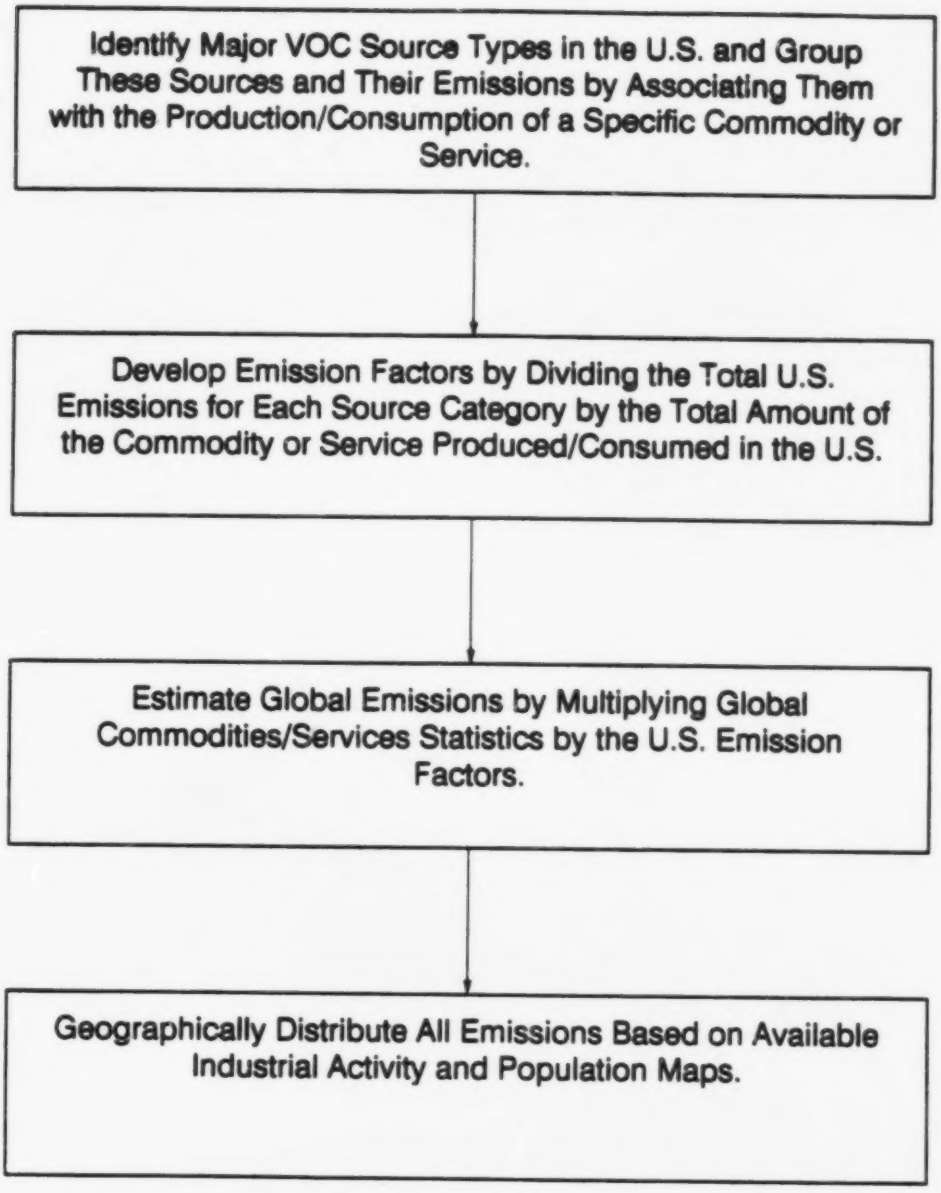
Identify Major VOC Source Types in the U.S. and Group These Sources and Their Emissions by Associating Them with the Production/Consumption of a Specific Commodity or Service.
Develop Emission Factors by Dividing the Total U.S. Emissions for Each Source Category by the Total Amount of the Commodity or Service Produced/Consumed in the U.S.
Estimate Global Emissions by Multiplying Global Commodities/Services Statistics by the U.S. Emission Factors.
Geographically Distribute All Emissions Based on Available Industrial Activity and Population Maps.

Figure 1. Technical Approach Used in Developing Global VOC Emission Inventory

Publications by the United Nations (UN), the U.S. Department of Commerce, and U.S. trade organizations contained data for 195 countries.

The final step in development of the inventory was the geographic distribution of the global emissions. Maps of individual countries were used to locate centers of population, industry, chemical manufacture, and petroleum refining. An atlas was used to locate the major deserts and forests on a continent basis. In general, emissions are distributed into grid cells of 10 degrees latitude by 10 degrees longitude. However, commodity and geographic data are stored at a higher degree of resolution.

1.3 CAVEATS

The inventory described in this document was intended to be an initial, limited effort at producing the needed data within tight budget and time constraints. Many of the assumptions used in the development of the inventory, described in Section 2, clearly introduce inaccuracies but were necessary in order to meet project constraints. For instance, application of emission factors derived from U.S. data to sources in less fully developed countries is not correct but was necessary because emission factor data are generally unavailable for such countries. However, it was felt that relatively early production of a gridded, speciated VOC inventory would meet needs in the scientific community and would encourage the application of additional resources to improve the accuracy. In addition, this initial inventory will be useful in planning future work to improve the resolution of the inventory data.

SECTION 2

TECHNICAL APPROACH

2.1 DEVELOPMENT OF GROUPS OF VOC SOURCES

2.1.1 Identification of Individual Sources of VOC

The first step in the development of the global VOC inventory was to identify the sources of VOC to be included. The 1985 NAPAP Emissions Inventory (Version 2), developed for the U.S. EPA under the National Acid Precipitation and Assessment Program (NAPAP), was used to identify these sources (Saeger et al., 1989).

Over 3000 different point and area sources are identified within the NAPAP inventory. Each source is included in the global VOC inventory using various simplifying assumptions and source aggregation techniques. Although the NAPAP inventory characterizes emission sources within the U.S., it is assumed that it contains data which can be used to represent many of the most significant VOC source types that exist around the world. Since industrialized nations likely account for a significant amount of the global anthropogenic VOC emissions, a national inventory for the U.S. includes data which represent many of the most significant global VOC sources. Exceptions to this are biomass burning, associated with land clearing (deforestation) for the creation of agricultural land and pasture, and savanna burning. Although these are not significant sources within the U.S., they are included in the global VOC inventory because studies have shown that they are significant global sources of CO_2 and potentially significant sources of VOCs (Houghton, et al, 1987; C. Veldt, 1988; Hao, et al, 1989).

Finally, although natural sources can significantly contribute to total VOC emissions in areas with substantial vegetation (B. Lamb et al, 1987), these VOC emissions are not included here, primarily because of resource and data constraints.

2.1.2. Grouping of Individual Sources of VOC

A useful aspect of the NAPAP VOC inventory is the organizational structure which allows a great deal of flexibility in the degree of VOC source aggregation or disaggregation used. In the NAPAP inventory, individual source types are organized into source categories which are assigned specific Source Classification Codes (SCCs). These SCCs are generally consistent with industrial and other activity classifications around the globe and they provide a convenient structure for organizing and grouping large numbers of individual source types. For example, emissions from all individual sources associated with petroleum refining operations in the United States can be grouped together by combining the data for all 8-digit SCCs which have 306 as the first 3 digits. In addition, the emissions can be grouped as a function of specific process operations associated with oil refining such as process heaters, catalytic cracking operations, vacuum distillation operations, and blowdown systems (6 digit SCCs: 306-011, 306-002, 306-006, and 306-004, respectively).

In developing the Source Groups included in the global VOC inventory, resource constraints dictated the necessity of reducing the over 3000 individual source types in the NAPAP inventory to a smaller and more manageable set of source groups. To achieve this, it was concluded that the Source Groups selected be logically related to available global "activity" data that could ultimately be used to estimate emissions from individual countries. After reviewing the types of available "global activity" data, it was apparent that general Source Groupings were possible using country-specific data such as coal and oil consumption, paint consumption, refinery crude oil throughput, wood utilization, deforestation statistics, population statistics, etc. For example, refinery crude oil throughput data are generally available for individual countries. Thus, it is logical to group all refinery-related VOC emission sources (e.g., production processes, product and raw material storage, boilers at refineries, fugitive sources, and crude oil production operations), and to group other VOC sources related to the use of commodities produced at refineries (e.g., gasoline storage, consumption, transportation and marketing), such that a country's refinery throughput can be used to estimate emissions from these sources.

Using the procedures described above, the approximately 3000 individual source types included within the NAPAP inventory were aggregated into 28 Source Groups which are listed in Table 1. Table 1 also describes some of the types of specific individual sources included within each of the 28 groups. Since so many individual source types of VOC can be included within a single Source Group, Table 1 identifies only representative source types.

Note that Group 27 (Miscellaneous Emission Sources) is a "catch all" group which contains a wide variety of individual and loosely-related source types. This group was created for several reasons. First, for many individual sources, reliable global statistics were not readily available which could be used to describe each source's level of activity within a country. Second, The NAPAP inventory includes a substantial number of very small and diverse individual VOC source types. To represent all of them within individual Source Groups would have required a substantial effort which ultimately would not have appreciably enhanced the accuracy of the final inventory. The combined emissions associated with all of the sources included in Source Group 27 account for about 7 percent of the emissions included in the global inventory.

2.2 IDENTIFICATION AND GEOGRAPHIC DISTRIBUTION OF THE GLOBAL ACTIVITY DATA ASSOCIATED WITH EACH VOC GROUP

2.2.1. Type of Global Activity Data

Table 2 identifies the global commodity, energy or other statistic selected to represent the "activity" associated with each Source Group. Due to limited project resources, it was decided to include only activity data contained within readily available sources (e.g., United Nations publications). The subsequent level of detail associated with the analysis was also limited by the somewhat general activity data contained within these sources.

TABLE 1. SOURCE GROUPS INCLUDED IN THE GLOBAL VOC INVENTORY

	Source Group Description	Representative Types of Sources Included
1	Oil and Natural Gas Production	- Oil well process operations - Natural gas well processes - Oil and gas field process heaters and steam generators - Oil and gas field fugitives - Oil and gas field flares
2	Coke Production	- Boilers firing coke oven gas - Coke manufacturing processes (e.g., charging, pushing quenching, coal handling)
3	Petroleum Refining	- Refinery operations (e.g., process heaters, crackers, distillation, waste water systems, cooling towers) - Co-generation units - Boilers burning process gas - Refinery flares
4	Gasoline: Storage, Consumption, Transportation and Marketing	- Use in light and heavy duty vehicles operating on all roads - Marine vessels - Service stations - Fuel storage and distribution (i.e., bulk terminals, bulk plants, airports, farms) - Fuel transport operations in tank cars and trucks
5	Distillate Fuel Oil: Storage, Transportation, and Marketing	- Fuel storage and distribution (e.g., various sizes and types of tanks) - Fuel transport (loading/unloading, other)
6	Crude Oil: Storage, Transportation, and Marketing	- Crude oil storage and transportation (e.g., various above and underground tanks, - Loading of crude oil tankers/barges
7	Other Petroleum: Storage, Transportation, and Marketing	- Underground storage tanks - Tank cars and trucks, marine vessels - Above ground storage tanks 8
8	Paper Coating Operations	- Coating operations, mixing and clean-up operations

TABLE 1. (Continued)

	Source Group Description	Representative Types of Sources Included
9	Surface Coating Operations	- Sources associated with the application of paints, lacquer, enamel, and primer to: cans, wood products, coils, metal parts, misc. - Use of thinning solvents
10	Printing and Publishing	- Lithography, rotogravure, and letter press operations - Use of thinning solvents
11	Rubber, Plastics, and Other Organic Chemical Manufacture	- Products: large volume organic chemicals, plastics and synthetic rubber, carbon black, printing ink, pharmaceutical, explosives - Source Types: process heaters, gas flares, incinerators, process sources of VOC, fugitive sources, waste sites (i.e., TSDFs associated with making these products)
12	Solvent Use	- Vapor degreasing, solvent extraction/recovery, textile mfg., dry cleaning
13	Paint Production	- Products: varnishes, oils, alkyds and acrylics, pigments, body oils - Sources: blending/mixing operations pigment handling, waste sites
14	Production of Automobiles and light Trucks	- Surface coating of automobiles and light trucks - Cleaning/degreasing operations
15	Pulp and Paper Industry	- Kraft, sulfite, and semi-chemical processing plants
16	Asphalt	- Paving operations
17	Bakeries	- Baking Processes
18	Diesel Vehicles	- Heavy duty and off-highway diesel vehicles/vessels
19	Aircraft LTOs	- Military, commercial, civil aviation Aircraft landings and Takeoffs (LTOs)

TABLE 1. (Continued)

	Source Group Description	Representative Types of Sources Included
20	Other Industrial and Utility Activities	- Utility and industrial boilers, - treatment, storage and disposal facilities (TSDFs) in inorganic chemical manufacturing and industrial gas manufacturing
21	Fuelwood Utilization	- Charcoal production - Residential wood combustion - Industrial/utility boilers
22	Refuse Disposal/other	- Residential waste incineration - Industrial on-site incineration - Structural fires
23	Deforestation for Agriculture	- Tropical area land clearing for crop production (associated biomass burning)
24	Deforestation for Pasture	- Tropical area land clearing for creation of pasture (associated biomass burning)
25	Managed Burning	- Prescribed burning
26	Forest Fires	- Wild forest fires
27	Miscellaneous Emission Sources	- Wide variety of industrial and other source types
28	Savanna Burning	- Savanna Burning

TABLE 2. GLOBAL ACTIVITY DATA USED TO ESTIMATE VOC EMISSIONS FROM EACH SOURCE GROUP

Source Group	Description	Global Activity Statistic
1	Oil and Natural Gas Production	Production of crude oil and natural gas
2	Coke Production	Production of coke
3	Petroleum Refining	Refinery throughput
4	Gasoline: Storage, Consumption, Transportation, and Marketing	Refinery throughput
5	Distillate Fuel Oil: Storage, Transportation, and Marketing	Refinery throughput
6	Crude Oil: Storage, Transportation, and Marketing	Refinery throughput
7	Other Petroleum: Storage, Transportation, and Marketing	Refinery Throughput
8	Paper Coating	Production of printing and writing paper, kraft paper and paper board, and other machine-made paper
9	Surface Coating Operations	Consumption of paint and allied products
10	Printing and Publishing	Consumption of printing inks
11	Rubber, Plastics, and Other Organic Chemical Manufacture	Production of ethylene, propylene, synthetic rubber, alkyd resins, amino resins PVC, polyethylene, polypropylene, other plastics
12	Solvent Use	Production of toluene, trichloroethylene, methyl alcohol, acetone, butyl alcohols, naphthas

TABLE 2. (Continued)

	Source Group Description	Global Activity Statistic
13	Paint Production	Production of paint and allied products
14	Production of Automobiles and light Trucks	Production of passenger cars, and trucks vehicles
15	Pulp and Paper Industry	Production of wood pulp by three processes: sulfate and soda, sulfite, semi-chemical
16	Asphalt	Asphalt production
17	Bakeries	Production of baked goods
18	Diesel Vehicles	Refinery throughput
19	Aircraft LTOs	Refinery throughput
20	Other Industrial and Utility Activities	Fossil fuel energy consumed within the industrial and utility sectors
21	Fuelwood Utilization	Production of fuelwood, residential fuelwood
22	Refuse Disposal/other	Population
23	Deforestation for Agriculture	Hectares of tropical forest cleared for crop production
24	Deforestation for Pasture	Hectares of tropical forest cleared for pasture
25	Managed Burning	Non-tropical forests
26	Forest Fires	Tropical and non-tropical forests
27	Miscellaneous Emission Sources	(see section 2.3.3 discussion)
28	Savanna Burning	Hectares of savanna land

The sources of global activity data used were:

- Energy Balances for Organization for Economic Cooperation and Development (OECD) Countries, 1985-1986 (OECD/IEA, 1988);
- 1986 Energy Statistics Sourcebook (PennWell,1986a);
- Oil and Gas Journal (PennWell,1986b);
- Energy Balances and Electricity Profiles For 1984 (UN, 1986b);
- 1984 Energy Statistics Yearbook (UN,1986c);
- Industrial Statistics Yearbook 1985 (UN, 1987);
- Handbook of Industrial Statistics 1986 (UN, 1986a);
- Food and Agriculture Organization (FAO) Land Use Statistics (UN,1980).

Many of these sources were obtained from the United Nations (UN) Statistical Office and include data for most countries of the world. In some cases, the data are based on actual data for a specific country, while in other cases the information provided is based on a "UN estimate" for that country. Little information was available regarding the basis of these estimates so judgments can not be made regarding how representative they are. The remainder of the discussion in this section describes some of the key issues associated with developing the "activity" data used in the inventory.

In order to estimate the average annual emissions associated with crude oil storage tanks and transport systems, some key assumptions were made in calculating the VOC emissions associated with the total annual throughput of crude oil within these systems. Specifically, for importing/exporting countries it was assumed that emissions associated with imports and exports are shared between the two countries involved. A simple procedure was developed which apportions the oil imported and exported between two countries based on an estimate of the residence time of the crude oil within both countries. Based on discussions with oil industry representatives, it is assumed that exported oil remains within the producing country an average of 45 days a year (one-eighth of a year) while imported oil remains within the receiving country for the remainder of the year (seven-eighths of a year).

This apportioning reduces the potential for double counting emissions associated with shared crude oil.

Source Group 20 contains a mixture of several industrial and utility sector sources. VOC emissions associated with disposing of the organic wastes from various industrial processes (e.g., inorganic chemicals manufacturing, industrial gas manufacturing) are included, as are the VOC emissions from several small industrial sources and the combustion of fossil fuel in the industrial and utility sectors. These sources are associated with general industrial and utility sector activity, so the decision was made to use a global "activity" statistic which is representative of the level of industrial and utility activity within a country, i.e., fossil fuel energy consumption in both the industrial and utility sector. Fossil fuel consumption in these sectors was selected since country-specific data were readily available and because fossil fuel represents a substantial portion of the total energy used within these sectors. It should be noted that use of fossil fuel alone as an indicator will cause emissions for this group to be underestimated in countries where a significant portion of the energy comes from non-fossil sources (e.g., nuclear power in France, hydro power in the Amazon and other regions). From a global perspective, this should not cause significant error in the total global VOC estimates. However, in using the inventory to conduct atmospheric chemistry studies, some uncertainty will be introduced into the estimated atmospheric concentrations for these countries. To identify the significance of this uncertainty and, if necessary revise the global VOC inventory, would require study beyond the scope of this effort.

Very little activity data were readily available for Taiwan; the UN does not report commodities statistics for that country. However, data for Taiwan, including the quantity of crude oil refined and the amount of PVC produced, were obtained from various trade journals and handbooks (The Oil and Gas Journal, World Rubber Statistics Handbook). These commodities are associated with several significant sources of VOC, so emissions estimates for sources linked with these commodities can be assumed to be as accurate as for most other countries included in this inventory. However, for the remaining data an alternative approach was used based on relationships developed from U.S. data. Specifically, all remaining activity data were estimated by multiplying U.S. PVC production and oil refining per-capita statistics by available Taiwan population statistics. As a check on the accuracy of this

technique, crude oil and PVC production data for Taiwan were estimated and compared against the published data described above. The agreement was generally poor: production of PVC was underestimated and crude oil refining was overestimated. A similar analysis was conducted using per-capita statistics for countries that more closely resemble the general structure of Taiwan; i.e., Japan and South Korea. However, little or no clear improvement occurred in the results. Again, if necessary this is another area requiring additional research but is beyond the scope of this effort.

For the deforestation Source Groups (Source Groups 23 and 24) the "activity" data selected was an estimate of the amount of land cleared by burning for the creation of crop land and pasture. In developing these estimates it was assumed that: (1) most land clearing of this type occurs in tropical regions, (2) about 36 percent of the land cleared for the creation of crop land is cleared by burning, and (3) about 50 percent of the land cleared for the creation of pasture is cleared by burning (Houghton et. al., 1983; Houghton et al, 1987). Estimates for tropical deforestation via burning were developed here using these key assumptions.

For savanna fires, a highly geographically resolved land use data base was used to estimate the number of hectares of savanna land on a global scale (Olson et al, 1985). Using techniques described later in this report, the amount of savanna land burned and the release of emissions per hectare were estimated.

2.2.2. Geographic Distribution of Activity Data and Emissions

As stated in Subsection 1.1, the primary focus of this effort was to develop a global VOC inventory for use with a two-dimensional global atmospheric chemistry model developed by Isaksen et al. (1985). This model requires that speciated VOC emissions data be aggregated into geographic grid cells. Based on the resolution of the data used to develop the emissions inventory, cells measuring 10 degrees latitude by 10 degrees longitude were used. There are a total of 648 such grid cells on the globe. To place VOC emissions in each grid cell, the commodities, energy, and other "activity" data selected to represent each of the 28 VOC Source Groups were first geographically located within each cell. Emission factors (the development of which is described in subsection 2.3.3) were then multiplied by this activity data to yield geographically resolved VOC emissions estimates.

The global activity data were available on a country-specific basis, so a means of locating this country-specific activity data on a map of the globe was developed and applied. For many countries, individual country-specific maps developed by the Central Intelligence Agency (CIA) were used. These CIA maps identify the location of several key activity centers within each country including:

- Population Centers (density)
- Industrial Centers
- Chemical Manufacturing Centers
- Refining Centers
- Forestry/Agricultural Areas

The geographical locations of these activity centers in each country were used to locate the activity data associated with each country into 10 by 10 degree grid cells. This made it possible for activity data associated with residential combustion sources to be proportionally distributed among population centers, paint production among industrial centers, and so on. For many small countries, maps were not used because their borders were contained completely within a 10 by 10 degree grid cell. For a few countries, maps identifying industrial, manufacturing, or chemical activity centers were unavailable. In these cases, activity data were distributed according to the distribution of the population within the country. For many European countries, the U.S., and Canada, data were reported at a higher resolution than 10 by 10 degrees. However, results are aggregated to the 10 by 10 degree level to maintain consistency with the other data used.

Table 3 identifies the activity center used to locate the activity data associated with each of the 28 Source Groups included in the global inventory. Depending on the size of the country and the diversity of the activity there, a number of latitude/longitude coordinates were determined for the activity centers. For example, there might be four population centers, two industrial centers, and one petroleum refining center. A percentage of the emissions was allocated to each point based on information contained on the CIA maps. This

TABLE 3. GEOGRAPHIC MAPPING FACTOR USED TO ALLOCATE COUNTRY-SPECIFIC ACTIVITY DATA INTO 10 BY 10 DEGREE GRID CELLS

Source Group	Description	Source Group Location
1	Oil and Natural Gas Production	Refining Areas
2	Coke Production	Industrial Areas
3	Petroleum Refining	Refining Areas
4	Gasoline: Storage, Consumption, Transportation, and Marketing	Population Areas
5	Distillate Fuel Oil: Storage, Transportation, and Marketing	Industrial Areas
6	Crude Oil: Storage, Transportation, and Marketing	Refining Areas
7	Other Petroleum: Storage, Transportation, and Marketing	Industrial Areas
8	Paper Coating Operations	Industrial Areas
9	Surface Coating Operations	Industrial Areas
10	Printing and Publishing	Population Areas
11	Rubber, Plastics, and Other Organic Chemical Manufacturing	Chemical Manufacturing Areas
12	Solvent Use	Industrial Areas
13	Paint Production	Industrial Areas
14	Production of Automobiles and Light Trucks	Industrial Areas
15	Pulp and Paper Industry	Industrial Areas
16	Asphalt Paving	Population Areas
17	Bakeries	Population Areas

TABLE 3. (Continued)

	Source Group Description	Source Group Location
18	Diesel Vehicles	Population Areas
19	Aircraft	Population Areas
20	Other Industrial and Utility Activities	Industrial Areas
21	Fuelwood Utilization	Industrial Areas
22	Refuse Disposal/Other	Population Areas
23	Deforestation for Agriculture	Tropical Forest Areas
24	Deforestation for Pasture	Tropical Forest Areas
25	Managed Burning	Non-tropical Forest Areas
26	Forest Fires	Tropical/Non-tropical Forest Areas
27	Miscellaneous Emission Sources	Industrial Areas
28	Savanna Burning	Savanna Areas

percentage was estimated based on a qualitative assessment of the fraction of the population (or industry, or refining) that the CIA map indicated was located at each point in the country (the maps indicated approximate size of the activity centers by varying the size of the symbols used to identify the activity centers). For example, if a map indicated that two refining centers were located in a country but one center was about two times larger than theother, then the refining capacity was allocated accordingly. Specifically, the smaller location was assigned one-third of the country's capacity while the larger location was assigned two-thirds.

For most Source Groups, the methodology described above was used (i.e., activity data were distributed into grid cells and then emission factors were used to calculate emissions). However, for deforestation via burning, forest fires, savanna fires, and prescribed burning, emissions were first calculated and then distributed directly into 10 by 10 degree grid cells based on the location of forests, savannas, and agricultural areas. As described in subsection 2.1.1, hectare estimates for deforestation via burning were developed for tropical regions. Using emission factors (see subsection 2.2.3), VOC emissions were estimated for biomass burning in the tropical areas of Asia, Africa, and America. These calculated VOC emissions were evenly distributed into 10 by 10 degree grid cells corresponding to the location of tropical forests on the African, American, and Asian continents. The table below summarizes the total VOC emissions estimated for each continent and the number of grid cells into which the emissions were distributed. A more rigorous location methodology for deforestation-related burning was not possible within the resource constraints of the project.

Source Group	Geographic Area	Total VOC (tons/yr)	Number of Grid Cells (10 × 10 degree)
23 & 24	Tropical Africa	2,399,437	8
23 & 24	Tropical America	1,552,893	11
23 & 24	Tropical Asia	881,689	12

Assuming that all managed burning in tropical forests is carried out for deforestation, emissions for Category 25 were distributed among nontropical forest areas. Since forest fires can occur in all types of forests, emissions for Category 26 were distributed among tropical and nontropical forest areas.

For savanna fires, geographically resolved estimates of the number of hectares of savanna were available on a global scale at a 0.5 degree by 0.5 degree resolution. These data, developed at the Carbon Dioxide Research Center in Oak Ridge, Tennessee, were used to locate the VOC emissions estimated here (Olson et al., 1985). Using the emission factors developed as described later, emissions were first calculated at the half degree level. These emissions were then aggregated up to the 10 by 10 degree level to maintain consistency with the other emissions estimates included in the inventory.

2.3. GROUPING INDIVIDUAL VOC SPECIES INTO SPECIFIC CLASSES AND DEVELOPMENT OF VOC CLASS-SPECIFIC EMISSION FACTORS

2.3.1. Overview

Different VOC species possess different characteristics with respect to their participation in atmospheric chemical reactions. VOCs can be categorized and placed into classes according to their chemical reactivities. Because the global VOC inventory was developed to be used in performing global atmospheric chemistry calculations (Isaksen, et al, 1985), it was necessary to categorize the VOCs in this way. Ultimately, a set of VOC species-specific emission factors were developed based on emissions data contained in the NAPAP inventory. To accomplish this, two sequential evaluations were conducted: first, VOC species and species classes were defined based on the atmospheric chemical reactivity associated with groups of VOCs, and second, the data and procedures necessary to develop speciated emission factors for these classes were developed. These two steps are discussed separately below.

2.3.2. Development of VOC Classes

The NAPAP emissions inventory contains total VOC emissions for individual source types. For each individual source type, total VOC emissions can be subdivided into emissions of individual component species using published VOC speciation profiles (Shareef et al, 1988). Species groups used here are generally consistent with the species groupings used in existing

state-of-the-art regional photochemical models (The NCAR Acid Deposition Modeling Project, 1985). Except for methane, all VOC species included in the global VOC inventory were placed into one of seven classes:

1 Paraffins
2 Olefins
3 Aromatics [benzene, toluene and xylene (BTX)]
4 Formaldehyde
5 Other Aldehydes
6 Other Aromatics
7 Marginally Reactive Compounds

Over 200 different organic compounds are included within these 7 classes. Class 1 includes a variety of branched alkanes, alcohols, esters and ketones, while Class 2 contains a combination of over 30 straight-chained and branched olefins. Class 3 includes the aromatics: benzene, toluene and xylene (BTX). These three aromatics are presented in a class separate from Class 6 aromatics because: (1) BTX is often used as a surrogate group to represent the overall reactivity associated with aromatic compounds, and (2) BTX is a class specifically required in Isaksen's model. The other aromatics in Class 6 include over 30 compounds with varying degrees of reactivity and are added to the inventory for completeness. Class 4 contains only formaldehyde, which is a very reactive VOC, and is subject to specific treatment in many photochemical models. Class 5 contains all aldehydes not contained within Class 4. Finally, Class 7 includes VOC's which are not significantly reactive, including most chlorinated and fluorinated hydrocarbons. This group was included in the inventory for completeness.

2.3.3. Development of Speciated Emission Factors

In this study, an emission factor describes the amount of emissions associated with one unit of a particular commodity, energy, or other activity statistic. For example, when a VOC emission factor for Source Group 2 (Coke Production) is multiplied by the annual production of coke in Canada, the result is an estimate of the annual average VOC emissions from the Canadian coke production industry.

Seven emission factors were developed for Source Groups 1 through 26, one each for the seven VOC classes described earlier. With the exceptions noted, emission factors were developed as described below:

1. Total speciated U.S. emissions were estimated for each Source Group based on the 1985 NAPAP Emissions Inventory (Version 2) (Saeger et al., 1989) and the NAPAP speciation profiles (Shareef et al., 1988).

2. These VOC species-specific emissions were then grouped into the 7 VOC classes described earlier.

3. For each Source Group, the U.S. emission estimates for each of the 7 VOC classes were divided by the activity statistic selected to represent that Source Group (see Table 2). For example, for Source Group 1, Oil and Natural Gas Production: an emission factor for VOC Class 1 was developed by dividing total paraffin emissions associated with oil and gas production sources in the U.S., by the U.S. production of crude oil and natural gas (in equivalent barrels of crude oil).

Because of the large and diverse number of source types included in Source Group 27 (Miscellaneous Emission Sources), it was necessary to establish a simple relationship to estimate global emissions from these sources in lieu of using global activity data and emissions factors. Most of the emissions associated with Source Group 27 are small to medium industrial sources. The emissions for Source Group 27 were estimated by multiplying the emissions associated with Source Groups whose emissions are located at industrial centers (Source Groups 2, 5, 7-9, 12-15, 20, and 21) by a factor based on U. S. emissions from miscellaneous, and industrial sources. This estimate is made for each 10 by 10 degree grid cell. The factors applied are listed below and were calculated by dividing the emissions in the U. S. associated with Source Group 27 by the emissions associated with the affected Source Groups. The percentages of total global emissions and U. S. emissions (including all the industrial and other sources included in the inventory) also are shown below to provide perspective. Although several of these apportionment factors appear to be quite high, it should be kept in mind that

the actual magnitude associated with the emissions from this group is low relative to total global emissions. Source Group 27 accounts for about 7 percent of the total emissions included in the global inventory.

VOC Class	Miscellaneous Emissions Factors Apportionment	Percent of Total Global Emissions	Percent of Total U. S. Emissions
1	0.18	46	60
2	0.33	35	14
3	0.17	13	13
4	1.12	1	2
5	3.09	0.2	1
6	0.83	4	9
7	0.26	0.8	1

As the data above show, for some individual VOC classes the percentage is slightly above 10 percent.

As described in Subsection 2.2.1., estimates were developed for tropical area deforestation burning which represent the total number of hectares cleared by burning. In order to estimate emissions, emission factors were developed which identify the amount and type of VOC emitted per hectare. The first step was to estimate weighted average fuel loading factors for each of the three tropical areas considered: Tropical America, Tropical Asia and Tropical Africa. These factors provide an estimate of the mass of wood available per hectare burned in each tropical region. The key assumptions associated with the development of these fuel loading factors, including estimates of the amount and type of forests existing in each tropical area, are summarized in the table below (Lanly, J., 1982):

Tropical Area	DESCRIPTION OF FOREST STATUS Unmanaged Forests (% total) Undisturbed	Logged over	Managed (% total)	Average Fuel Loading Factor (m^3/ha)
CLOSED-BROADLEAF FORESTS				
America	89	11	0	153
Africa	73	26	1	239
Asia	51	30	19	160
CONIFEROUS FORESTS				
America	10	87	3	79
Africa	46	50	3	112
Asia	32	17	52	148

As shown in the table, for each forest type and geographical region identified above, an average fuel loading factor was estimated. These average fuel loading factors were used to develop a set of weighted averaged factors for each of the three tropical regions. This was done using average wood density assumptions (coniferous wood: 625 kg/m^3, and broadleaf wood: 750 kg/m^3), and estimates of the percentage of broadleaf versus coniferous forests that exist in each tropical area (Lanly J., 1982). The weighted average fuel loading factors for each region are:

Tropical America = 113 Mg/ha
Tropical Africa = 176 Mg/ha
Tropical Asia = 119 Mg/ha

Using the fuel loading factors listed above, a total VOC emission factor was developed from available emission factors for the combustion of forest residues (U.S. EPA/ AP-42; 1985). An average factor of 7.2 kg VOC/Mg residue was used to represent both broadleaf and coniferous forest residues. This value includes both methane and non-methane hydrocarbons. A VOC species-specific set of emission factors was developed based on a speciation profile typical of prescribed forest burning activities (Shareef G. et al, 1988).

For managed burning and forest fires (Source Groups 25 and 26, respectively) a very simple emission factor was developed based on emissions from these sources within the U.S. Specifically, VOC species-specific emissions in the U.S. were divided by the number of 10 by 10 degree grid cells within the U.S. which contain forest land (estimated to be about 3.5 cells). This yielded a crude emission factor which estimates the amount of VOC per grid cell in forested areas. Emissions were added accordingly to each grid cell on the globe which contained a significant amount (greater than approximately 50 percent) of forest land.

For savanna fires, emission factors were developed on a continental basis for America, Africa, Asia, and Australia. These factors were developed to represent a combination of key assumptions for each continent regarding the tons of biomass burned per hectare of savanna, the release of emissions per ton of biomass burned, and the distribution of VOC species. Emission factors representing total VOC emissions from savanna fires are shown below along with the key assumptions used in their development (Hao et al., 1989; EPA AP-42,

1985). Total emissions were speciated into specific VOC classes based on the assumption that 90.5 percent of the non-methane hydrocarbon emissions from savanna fires are assumed to be olefins such as ethylene, propene, acetylene, butene and others, and the remaining 9.521 percent are assumed to be paraffins such as ethane. These assumptions were based on data reported by Bonsang et al. (1990).

Area	Biomass Burned (tons per hectare per year)	Average Period Between Fires (years)	Emissions Rate[a] (tons per ton of biomass burned)
America	2.8	2	0.0224
Africa	4.0	1.33	0.0320
Asia	2.1	2	0.0168
Australia	1.0	16	0.0080

[a] Based on the biomass burned estimates in the table and an average emission factor from EPA AP-42 for grasses and wild hay of 0.008 ton of VOC per ton of biomass burned.

SECTION 3

DISCUSSION OF UNCERTAINTIES

This discussion identifies key uncertainties associated with (1) the raw data used to develop the inventory, and (2) the methods used to interpret and use the data to estimate emissions. Additional uncertainties that should be taken into account when using the inventory to perform analysis are also discussed.

3.1 UNCERTAINTIES IN THE RAW DATA USED TO DEVELOP THE INVENTORY

Two basic data bases were used to prepare the global inventory: the NAPAP emissions inventory (used to develop emission factors for the Source Groups included), and global activity data (used to estimate total emissions for these Source Groups). The uncertainties that exist in both data bases are discussed below.

Some of the emission factors used to develop the 1985 NAPAP inventory are of unknown quality and as such, these results must be viewed with caution (Shareef et al., 1988). Some quality ratings have been estimated for the VOC speciation profiles used in this study to develop emission factors for specific VOC classes (Shareef, et al., 1988). These quality ratings are qualitative judgments of data quality and are represented by the assignment of ratings "A" through "E"; the definitions for which are given in Table 4. The quality ratings defined in Table 4 describe the relative confidence associated with the measurements and other data used to develop the original speciation profile. They also provide a general guideline which describes how representative a profile is with respect to the population of sources it is intended to represent. A substantial number of these profiles contain "D" and "E" ratings. This raised the possibility that significant uncertainty may have been introduced into the global VOC inventory

TABLE 4. VOC SPECIATION PROFILE RATING DEFINITIONS

Profile Rating	Rating Definition/Criteria
A	Based on a composite of several tests using analytical techniques such as GC/MS and can be considered representative of the total population.
B	Based on a composite of several tests using analytical techniques such as GC/MS and can be considered representative of a large percentage of the population.
C	Based on a small number of tests using analytical techniques such as GC/MS and can be considered reasonably representative of the total population.
D	Based on limited measurements data and in some cases on calculated values.
E	Based on calculated values and engineering judgments. May not be considered representative of the total population.

so a qualitative evaluation was conducted to examine the extent to which this uncertainty may have effected the global inventory.

The first step in the process to evaluate the uncertainty associated with the speciation profiles was to determine an aggregate or weighted average quality rating for each Source Group. Within each Source Group, there are several individual sources each with its own VOC speciation profile and profile quality rating. To perform this analysis, an aggregate of these individual source ratings was developed. First, profile ratings of A through E for individual sources were assigned numerical values of 1 through 5, respectively. Next, VOC speciation profile weighing factors for each individual source within a Source Group were calculated by dividing the total U.S. emissions from each individual source by the total U.S. emissions associated with the Source Group (i.e., large sources within the Source Group were given a large weight and small sources were given a small weight). For example, consider a hypothetical Source Group which contains only two individual sources: source X and source Y. The weighted profile quality rating for this Source Group was calculated using the data as illustrated below:

Item	Profile Rating	Numerical Profile Rating	U.S. Emissions Emissions (tons)	Weight Factor[a]	Weighted Profile Rating[b]
Source X	A	1	80	0.8	0.8
Source Y	E	5	20	0.2	1.0
Source Group	B+	-	100	-	1.8

a. e.g., source x emissions /(source x emissions + source y emissions)
b. (numerical profile rating)(weight factor)

Table 5 presents the results of this evaluation. The overall weighted quality rating for the global inventory is estimated to be between C and D. This was determined by first calculating a weighted quality rating for each Source Group and then summing the weighted ratings for all Source Groups. The weighing factor was calculated based upon each Source Groups contribution to total global emissions (i.e., Source Groups emissions divided by global emissions). This overall rating does not include Miscellaneous Emission

TABLE 5. WEIGHTED AVERAGE QUALITY RATINGS FOR THE VOC PROFILES USED FOR SELECTED SIGNIFICANT SOURCES

Source Grouping	Contribution to Total VOC Emissions in the Global Inventory, %	Weighted Average VOC Speciation Profile Quality Rating
Fuelwood Utilization	20	D
Savanna Burning	16	Rating not available
Gasoline: Storage, Transportation, and Marketing	16	C+
Refuse Disposal	18	D
Miscellaneous Emissions	7	Rating not estimated
Rubber, Plastics, and Other Organic Chemicals	7	E
Solvent Use	7	D+
Deforestation and Agriculture	3	D
Surface Coating Operations	2	C+
OVERALL Profile Rating For the Inventory[a]	-	C to D

a. Includes all groups in the inventory except Miscellaneous Emission Sources and Savanna Burning.

Sources. A substantial effort would have been required to estimate a weighted profile quality rating for this group due to the large number of individual sources included there. The overall profile rating also does not include savanna burning because no quality rating was available for the speciation of that category.

The data in Table 5 show that significant uncertainty exists in the weighted average speciation profiles associated with many individual Source Groups. For example, almost 23 percent of the global VOC emissions are associated with combustion of biomass (Fuelwood Utilization, Deforestation for Agriculture and Pasture) and each of the speciation profiles associated with these sources are D rated. Clearly, if additional measurements of the VOC species emitted from these similar sources were available, the uncertainty associated with this inventory could be dramatically reduced.

Table 5 also shows that the ratings for the Source Groups: Refuse Disposal; and Rubber, Plastics and Other Organic Chemicals are D and E, respectively. Together, these three Source Groups account for about 15 percent of the total VOC included within the inventory. As before, additional measurements data for these Source Groups could also have a significant effect on the overall rating for the global inventory. However, these groups account for a rather large number of individual and significantly different source types. For this reason, obtaining all the measurements data necessary to improve the quality rating for the Source Groups could be a substantially greater effort than the effort discussed above for the biomass combustion sources.

It should be emphasized that the quality ratings presented in Table 5 describe the uncertainty in the data used to speciate total VOC emissions from the NAPAP inventory into its individual component VOC species. These ratings do not characterize the uncertainty associated with the NAPAP total emissions estimates themselves. Thus, the quality ratings do not reflect the uncertainty associated with the overall inventory since it was developed based on both the total VOC estimates and speciation data. In general, ratings for total VOCs are not available but in some cases they are. For example, the emission factors used to estimate total emissions from savanna fires have been assigned a B rating (EPA AP-42, 1985).

Finally, an overall concern surrounding use of UN commodities statistics is that they lack independent review and verification (i.e., data from

individual countries are published without an independent check even if the data are suspect). In addition, there are no quality rating indicators provided with this data. Therefore, an evaluation of how the quality of this data may impact the global inventory was not conducted. An independent check of the U.N. data could be conducted by comparing data from other sources such as trade and other organizations.

3.2 UNCERTAINTIES IN THE INTERPRETATION OF THE DATA

The use of the NAPAP inventory data as a basis for emission factors applied in the global VOC inventory involves the implicit assumption that the emission characteristics of specific sources in other countries are similar to those of the United States. While this may be a reasonably valid assumption for many of the industrialized nations, emissions from developing countries whose VOC sources may differ significantly from those in the U.S. may be over- or under-estimated.

First, it is unlikely that the level of VOC emissions control around the world is uniform. For example, in the United States, there is a tendency to control chemical production process off-gases by either reclaiming the VOCs (e.g., use of absorption, adsorption, and/or condensation techniques) or by incinerating the VOC in thermal or catalytic combustion device. Very few large sources of VOC are vented directly to the atmosphere without some sort of emissions control. In developing countries, it is likely that application of emission controls is of a lower priority and consequently, less VOC is removed, or the process off-gases are simply vented directly to the atmosphere.

A second but equally important source of variation is that the processes and equipment used in the industrial and other sectors may also differ significantly between developed and developing countries, and, to some extent, even between developed countries. Technological differences in the transportation fleet, refining and organic chemical manufacturing processes, residential and industrial waste handling, and general industrial processes could all affect the magnitude and distribution of VOC emissions around the world. Although these considerations could potentially result in some inaccuracies within the inventory, to reduce or eliminate them would require a more detailed and rigorous country-by-country analysis. Although this level

of analysis may be desirable, the level of resources necessary to perform such an analysis would be significant.

Finally, use of global commodities data to estimate the level of activity associated with the Source Groups included in this study also introduces some uncertainty into the inventory. In general, the approach provides only an approximation of the activities associated with all the individual sources contained within each Source Group. For example, Source Group 11: Rubber, Plastics, and Other Organic Chemical Manufacturing includes the emissions associated with manufacturing all organic chemicals which emit VOCs to the atmosphere (clearly a very long list of chemicals). The global commodity statistic used to represent the activity associated with Source Group 11 is an aggregate weight of several key feedstock and end-product chemicals including: ethylene, propylene, polyethylene, polypropylene, PVC, synthetic rubber, and others. Some individual sources included in the development of the emission factors for Source Group 11 are not directly related to these feedstocks or products (e.g., chemicals where benzene, toluene or other feedstocks are used to produce them). As a result, the commodity chosen for Source Group 11 does not directly reflect the activity associated with the manufacture of all chemicals. Rather, it simply provides a general indication of the organic chemical production activity within a country, and presumably, provides an indication of the approximate production level associated with all organic chemicals. Hopefully, by choosing some of the largest volume chemical feedstocks and products to represent the activity associated with Source Group 11, the uncertainty has been minimized for the countries with large VOC emissions from industrial sources.

3.3 UNCERTAINTIES ASSOCIATED WITH THE USE OF THE INVENTORY

Another important point to consider when using the NAPAP inventory is that the emissions estimates contained within the inventory represent annual average emission rates for individual sources. For some sources such as biomass burning (wood combustion and savanna fires), significant variations may occur from month to month, and/or from season to season. Knowledge of the magnitude of these variations could potentially enhance the accuracy of global ozone estimates because ozone formation is generally cyclic, and depends on the atmospheric conditions present. For example, the "ozone season" generally

occurs during the summer months so average summer emissions rates for specific areas may result in more accurate "ozone season" estimates than may result if annual average estimates were used. In order to conduct realistic impact studies, knowledge of the concentrations that exist during the "ozone season" must be considered. It is desirable for analyses to be conducted to identify those most globally significant VOC sources which are cyclic in nature and to evaluate the significance of any cycles found on global ozone concentration estimates.

Finally, this inventory should be considered relatively complete with respect to its coverage of anthropogenic sources of VOC; natural emissions of VOC have not been included. Preliminary estimates have shown that natural emissions of nonmethane hydrocarbons contribute 30.7 Mt annually within the United States alone or approximately 2 times that of anthropogenic sources (B. Lamb et al., 1987). As a result, users of this inventory are encouraged to include a background estimate of naturally occurring VOC if a total global flux of VOC is desired.

SECTION 4

SUMMARY OF RESULTS

The detailed results of this study -- a spatially disaggregated global inventory of VOC emissions -- are presented in the Appendix. Emission estimates for each of the 7 reactivity classes are given in tons per year for each of the 648 grid cells of the globe. Results show total emissions of over 120 million (120,555,486) tons of VOC per year.

Table 6 lists the speciated emissions by country. The U.S. is the largest emitter with 21.5 million tons/year of VOC emissions or 18 percent of the total emissions for the globe.

With the exception of the U.S. and Canada, the values shown in Table 6 do not include emissions from deforestation for agriculture/pasture, managed burning, forest fires, and savanna fires (Source Groups 23, 24, 25, 26 and 28). This is because forestry-related emissions were generally estimated on a continental, rather than per-country basis. For example, for the Asian countries, these emissions are aggregated as managed burning/forest fire emissions from all countries in Tropical Asia. Of all these source groups, emissions from savanna burning are the most significant, accounting for almost 20 million tons or 16 percent of the total emissions in the inventory.

The inventory is presented by Source Group in Table 7. The results of this study indicate that a relatively small number of Source Groups account for a large fraction of the total VOC emissions included in the global inventory. These Source Groups are listed below in rank order. The percents shown for total VOC emissions are approximately the same as the cumulative percents for reactive VOC emissions (i.e., reactive VOC classes: 2,3,4 and 5) so the influence of these Source Groups on atmospheric chemistry can also be considered to be very significant.

TABLE 6. GLOBAL VOC EMISSIONS BY COUNTRY (tons / year)

	Total	Paraffins	Olefins	Aromatics (BTX)*	Formal-dehyde	Other Aldehydes	Other Aromatics	Marginally Reactive
United States of America	20986850	12755680	2775660	2790747	335150	112019	1927447	290145
Union of Soviet Socialist Republics	8571667	5109235	1309533	1193883	177185	47211	610732	123884
Tropical America (biomass burning)	6209200	1099317	5109883	0	0	0	0	0
China (Mainland)	5885509	2551730	2007049	1138174	32726	14219	113368	28240
India	5670019	2303248	1991314	1295687	15173	6706	40538	17350
Japan	4269605	2727158	527770	491824	63363	22137	350287	87062
Brazil	4158277	1816224	1228286	986627	19100	5648	82643	19746
Germany, Federal Republic of	2937097	1901637	344424	337315	38014	13486	240133	62085
Indonesia	2693277	1074179	894921	687923	8202	2293	22109	3647
Canada	2567184	1832993	229196	210739	40107	10126	170716	73304
France	2082527	1242864	314572	279664	28976	10520	174509	31420
Nigeria	1917240	765533	626410	494895	4310	1769	21897	2422
Tropical Africa (biomass burning)	17342702	2376603	14966099	0	0	0	0	
United Kingdom	1643930	1015521	214029	201883	28279	8946	153573	21698
Mexico	1565216	996092	233568	185206	23313	5512	92441	29080
Tropical America	1552893	691890	861003	0	0	0	0	0
Italy	1397750	893743	200414	136984	25767	7133	107808	25897
Asia	1211135	539620	671515	0	0	0	0	0
Europe (biomass burning)	956160	426016	530144	0	0	0	0	0
Tropical Asia (biomass burning)	955838	399324	556514	0	0	0	0	0
Thailand	846081	338916	277773	212868	3385	1119	10533	1483
Tanzania	834270	310601	285640	236229	315	161	971	350
Spain	763691	464994	116113	92028	13760	3907	61113	11772
China (Taiwan)	759076	475686	104263	114732	8973	2761	34808	17850
Ethiopia	719297	271612	248812	195937	484	271	1565	613
North America	701183	312411	388772	0	0	0	0	0
Netherlands	687113	428770	96022	70369	16263	4707	60654	10324
Romania	685360	461875	85343	70637	11553	3466	33320	19163
Philippines	673525	270351	225821	166552	2551	661	6499	1086
Bangladesh	668482	265959	240499	153216	1370	894	4423	2117
Australia	608520	346955	89919	89542	11526	3533	63425	3617
Kenya	598435	225556	203413	166725	616	183	1595	346
Pakistan	578554	240817	200389	122855	2705	1231	8252	2302
Zaire	569660	216674	196994	152937	421	258	1801	571
Korea, South	569099	333282	112485	75648	7514	2252	27856	10059
Poland	530474	329350	92265	55399	7133	2681	31371	12272
Vietnam	512549	201477	181211	123757	719	537	3564	1281
Australia and New Zealand	509951	227208	282743	0	0	0	0	0
German Democratic Republic	509730	347640	48117	58150	8255	1675	33350	12540
Argentina	502709	259616	107910	90110	7938	2042	32677	2412
Colombia	468766	214348	130195	99102	3990	1243	18365	1520

Table 6. (Continued)

	Total	Paraffins	Olefins	Aromatics (BTX)[a]	Formaldehyde	Other Aldehydes	Other Aromatics	Marginally Reactive
Yugoslavia	460994	266851	77216	70371	5781	1874	31951	6946
Czechoslovakia	453437	289506	64543	47681	6790	2494	31600	10819
South Africa Customs Union	442196	218449	99970	89158	5199	1213	26695	1510
Turkey	435645	201044	129664	83955	4560	991	13682	1746
Sweden	427243	234151	69848	78118	6775	1661	32971	3716
Venezuela	386051	241511	48949	41691	11827	2106	38142	1822
Sudan	368055	141377	126055	97606	511	219	1812	472
Burma	367070	145029	127569	90126	763	355	2524	701
Iran	352415	206417	67921	39922	8947	1581	26014	1609
Saudi Arabia	321434	217738	31830	27791	9807	1250	31985	1030
Nepal	304015	114583	105731	82632	140	113	537	276
Hungary	289439	169880	49805	40608	3764	1454	18651	5274
Mozambique	288511	109703	98775	78189	272	129	1133	306
Bulgaria	278547	172799	40849	33767	4524	1325	19818	5462
Belgium	245442	152396	31152	31404	6145	1126	20126	3089
Malaysia	232156	107336	64784	49154	2156	475	7749	499
Finland	231361	122804	39688	47176	4298	818	15058	1515
Egypt	230446	127572	57841	26244	4930	892	11745	1219
Uganda	224278	85440	77937	59607	156	115	767	253
Peru	215724	99673	61455	43890	2423	545	7098	637
Algeria	211975	131806	33367	28042	4994	651	10623	2490
South America	191231	85203	106028	0	0	0	0	0
Austria	190809	102857	30043	35874	3221	904	16962	946
Cameroon	189175	78936	59075	46562	923	191	3234	250
Zambia	187669	71547	63360	51370	241	80	914	154
Chile	182893	81822	52721	39848	1525	371	6132	470
Sri Lanka	181311	72007	62019	45025	498	142	1300	317
Ecuador	1749[illegible]	79806	48675	38396	1414	315	6039	346
Norway	174126	110538	22694	22225	2863	802	12477	2524
Cuba	172199	88969	37213	28878	2504	649	13352	631
Ivory Coast	170341	66995	56845	44407	500	126	1267	198
Portugal	167813	106972	23217	20534	2675	559	10403	3451
Australia (savanna burning)	166432	14563	151869	0	0	0	0	0
Ghana	162085	63813	55416	40983	356	120	1151	242
Angola and Cabinda	160742	63520	53724	42127	336	90	755	188
Korea, North	146564	65343	45565	28536	1040	434	5027	616
Sierra Leone	145985	54626	49896	41031	84	32	242	70
Guatemala	145078	57017	48418	37573	312	117	1435	203
Switzerland and Liechtenstein	139593	77268	23220	21317	2127	678	14434	545
Greece	137920	75220	28709	20604	3180	542	9074	587
Burkina Faso (Upper Volta)	131794	50237	45554	35093	102	74	560	170

Table 6. (Continued)

	Total	Paraffins	Olefins	Aromatics (BTX)*	Formal-dehyde	Other Aldehydes	Other Aromatics	Marginally Reactive
Malawi	126237	47940	43559	33952	89	64	484	147
Afghanistan	125920	50522	44425	28725	217	154	1549	325
Zimbabwe	125027	48621	42516	32326	161	107	1093	200
Madagascar	122858	48233	41914	31080	201	107	1092	229
Haiti	114398	43361	39401	30957	76	55	421	125
Papua New Guinea	108968	41181	36946	30102	90	51	512	82
Denmark	107003	61334	15547	16907	2026	436	10118	632
Rwanda	105996	40164	36558	28665	69	50	368	119
Singapore	104723	72422	9373	5968	8300	630	7885	143
Iraq	102394	65778	17582	8483	2395	387	7267	499
El Salvador	99983	39093	33498	26088	224	73	873	130
Kuwait	98909	70476	7642	7867	5221	545	6712	443
Mali	98727	38056	34396	25494	88	64	486	140
Paraguay	97024	37063	32572	26533	109	49	607	88
Democratic Kampuchea (Cambodia)	96943	36776	33737	25905	64	50	283	124
Honduras	94208	36397	31628	25138	150	62	727	103
Somalia	89647	34432	30366	24041	153	54	503	95
New Zealand	88846	49953	11525	14804	1624	534	9911	493
Libya	88797	55032	11931	12337	1983	444	6672	396
Morocco	83680	41049	26823	11087	1168	257	2762	530
Benin	83436	31530	28700	22759	49	36	278	82
Senegal	80152	31676	27169	20194	166	68	753	124
Tunisia	79362	34784	23625	18144	571	161	1833	240
Puerto Rico	78940	47732	10642	9043	2208	433	8568	311
Niger	78650	30236	27291	20456	78	55	406	126
Laos	76958	29105	26706	20763	47	36	208	89
Liberia	76492	29505	25342	20922	165	31	467	55
Burundi	74102	28200	25689	19749	53	40	270	98
Guinea	68292	26508	23727	17348	77	55	445	128
Israel	66038	39559	9133	9007	1656	265	5977	438
Chad	65411	25126	22752	17003	61	45	316	105
Uruguay	63891	26231	20225	15978	327	58	978	91
Albania	59890	28245	14236	10376	880	117	5923	109
Nicaragua	59490	23663	19567	15254	161	54	703	86
Central African Republic	58363	22057	20056	15927	36	25	202	57
Syria	58212	35944	10887	4543	1972	187	4417	259
Bhutan	55926	20802	19205	15795	15	12	64	30
Costa Rica	55543	22009	18152	14423	154	46	688	68
United Arab Emirates	55377	39479	5121	4498	1738	297	4044	197
Ireland	51371	28704	7947	7696	838	336	5467	382
Bolivia	46154	21521	13599	8556	430	133	1749	162

Table 6. (Continued)

	Total	Paraffins	Olefins	Aromatics (BTX)[a]	Formaldehyde	Other Aldehydes	Other Aromatics	Marginally Reactive
Panama	44471	19471	12974	10425	429	59	1044	65
Dominican Republic	44448	21070	12484	8296	439	109	1863	184
Netherlands Antilles and Aruba	38501	30196	1507	1856	3579	26	1309	26
Mongolia	35922	15244	10708	8493	120	64	1211	79
Qatar	34899	22322	4777	2869	971	399	3023	535
Congo	34270	13856	11256	8802	39	23	248	43
Trinidad and Tobago	32786	21385	3713	3220	1289	214	2795	167
United States Virgin Islands	31362	24961	1113	1549	3022	26	669	19
Gabon	31295	14443	8491	7407	278	34	597	42
Oman	29259	18739	3123	3364	785	314	2655	277
Hong Kong	29029	14965	8149	3260	205	173	1958	317
Bahrain	26507	19187	1693	1710	2083	184	1501	146
Lebanon	23490	11407	6502	4007	266	74	1130	102
Yemen, People's Democratic Republic of	22658	12755	4698	3100	716	80	1227	78
Yemen	20813	10478	6542	2238	133	84	1178	158
Jordan	20532	12326	3417	1984	603	81	2025	94
Togo	16594	6717	5975	3616	33	25	166	59
Gambia	15910	6145	5305	4271	16	9	143	18
Jamaica	13557	7539	2850	1742	265	52	1029	78
Bahamas	11083	8643	559	578	1009	11	268	11
Luxembourg	10625	5979	1598	1454	134	66	1340	52
Guinea-Bissau	9572	3739	3318	2401	11	8	72	19
Brunei Darussalam	9383	5931	1257	1269	193	84	573	73
Equatorial Guinea	8740	3290	2973	2429	4	3	31	6
Cyprus	6594	3802	1190	758	149	27	634	30
Guam	5087	3318	560	460	288	34	411	13
Mauritania	4835	2373	1659	478	31	20	229	43
Reunion	4771	2503	1042	656	62	29	454	23
Martinique	4675	2754	713	615	114	18	438	20
Solomon Islands	4543	1768	1514	1199	4	3	45	6
Guyana	3740	1920	994	478	30	16	276	23
Fiji	3725	1854	949	606	23	12	257	22
Mauritius	3569	1758	1136	409	24	15	197	27
Iceland	3540	1956	617	428	67	29	422	19
Antigua and Barbuda	3536	2036	474	470	42	20	477	14
Belize	3377	1427	993	823	11	5	109	6
Barbados	2906	1671	452	409	57	11	288	14
Guadeloupe	2816	1503	600	380	26	13	276	14
Suriname	2549	1331	560	375	26	12	227	15
Malta	2263	1250	487	239	22	11	232	19
Samoa (Western Samoa)	2261	991	640	521	7	4	89	6

Table 6. (Continued)

	Total	Paraffins	Olefins	Aromatics (BTX)[a]	Formaldehyde	Other Aldehydes	Other Aromatics	Marginally Reactive
French Guiana	2125	945	551	510	7	3	101	5
New Caledonia	2011	1114	349	247	35	15	240	9
French Polynesia	1859	1007	310	293	24	10	202	10
Djibouti	1185	595	392	106	8	5	66	10
Macau	1043	548	296	98	8	4	77	8
Bermuda	853	480	143	105	9	4	102	4
Cape Verde	836	405	305	79	4	3	30	7
Vanuatu	835	365	268	165	3	1	27	3
Comoros and Mayotte	827	398	318	64	5	3	28	8
Saint Lucia	820	441	167	116	6	3	79	5
Pacific Islands	770	414	181	85	7	4	72	5
Faeroe Islands	567	319	96	71	6	3	68	2
American Samoa	515	227	139	46	41	15	43	1
Seychelles	455	241	92	68	4	2	42	2
Grenada	444	233	120	45	3	2	35	3
Saint Vincent and the Grenadines	427	218	131	40	3	2	27	3
Cayman Islands	382	218	56	49	4	2	49	1
Dominica	380	201	92	46	3	1	32	2
Maldives	373	182	137	30	2	1	15	3
Sao Tome and Principe	342	178	96	34	2	1	26	2
Tonga	331	167	101	31	4	2	22	2
Greenland	328	178	71	37	3	1	33	2
Timor (East Timor)	254	141	36	32	3	2	34	3
Saint Christopher and Nevis	254	136	59	28	2	1	24	1
Nauru	205	117	29	26	2	1	26	0
Western Sahara	197	113	24	26	2	1	27	1
Gibraltar	190	103	42	21	1	1	19	1
Kiribati	156	77	54	12	1	0	7	1
British Virgin Islands	140	80	21	18	1	0	18	0
Cook Islands	134	63	37	12	7	2	10	0
Montserrat	121	67	22	14	1	0	13	0
Andorra	67	31	28	4	0	0	1	0
Monaco	54	25	22	3	0	0	1	0
Saint Pierre and Miquelon	44	24	9	5	0	0	4	0
San Marino	41	19	17	2	0	0	0	0
Falkland	35	20	5	4	0	0	4	0
Saint Helena	31	12	11	6	0	0	0	0
Tuvalu	15	7	6	1	0	0	0	0
Niue	13	6	5	0	0	0	0	0
Vatican City	1	0	0	0	0	0	0	0
Wake Island	0	0	0	0	0	0	0	0

[a]BTX = benzene, toluene, and xylene.

TABLE 7. GLOBAL VOC EMISSIONS BY SOURCE GROUP (tons / year)

Source Group (No.)	Total	Paraffins	Olefins	Aromatics (BTX)*	Formal-dehyde	Other Aldehydes	Other Aromatics	Marginally Reactive
Fuelwood Utilization (21)	24474369	9316136	7654339	7503543	0	31	225	92
Savanna Burning (28)	19840168	1884816	17955352	0	0	0	0	0
Gasoline: Storage, Consumption, Transportation, & Marketing (4)	19326219	10979580	2479923	2800082	131454	53292	2881884	1
Refuse Disposal / Other (22)	9083206	4259054	3895003	625249	41722	33916	144009	84252
Miscellaneous Emission Sources (27)	8781374	3660047	2747703	1722517	111401	54819	356482	128401
Rubber, Plastics, & Other Organic Chemical Manufacturing (11)	8118440	4760237	1674775	540519	39593	80470	834139	188705
Solvent Use (12)	7968357	7218666	38372	168938	34753	0	86758	420867
Petroleum Refining (3)	4137574	3501570	85026	52509	494568	36	3566	296
Deforestation for Agriculture (23)	3825950	1704648	2121302	0	0	0	0	0
Surface Coating Operations (9)	3415649	1822136	221918	1136432	1264	15	214631	19249
Managed Burning (25)	2301206	1025300	1275906	0	0	0	0	0
Forest Fires (26)	1970637	878015	1092622	0	0	0	0	0
Diesel Vehicles (18)	1243808	967906	0	0	120953	65744	7726	81478
Other Industrial & Utility Activities (20)	982383	512877	132045	165484	45716	14332	76158	35768
Paper Coating Operations (8)	795647	415609	2	374743	0	0	5291	0
Asphalt Paving (16)	659754	315058	45634	0	0	0	299061	0
Printing & Publishing (10)	640155	491831	11397	8858	3416	0	112589	12062
Oil & Natural Gas Production (1)	596007	565045	13945	6533	3659	931	3775	2115
Bakeries (17)	474610	225885	99295	51275	10392	7080	59840	20841
Aircraft (19)	333118	83298	137380	12761	64918	24254	10505	0
Coke Production (2)	317392	103263	125743	65604	3127	2542	10794	6315
Deforestation for Pasture (24)	305887	136287	169599	0	0	0	0	0
Other petroleum: Storage, Transportation, & Marketing (7)	304593	197629	3412	95557	0	0	7990	1
Crude oil: Storage, Transportation, & Marketing (6)	286201	281693	0	4508	0	0	0	0
Production of Automobiles & Light Trucks (14)	222706	107040	918	95197	51	41	19353	103
Pulp & Paper Industry (15)	66849	41274	5368	4913	13984	73	1052	182
Paint Production (13)	65691	26938	5649	27113	822	668	2838	1660
Distillate Fuel Oil: Storage, Transportation, & Marketing (5)	17536	16805	0	730	0	0	0	0

*BTX = benzene, toluene, and xylene.

Group	Percent of Total VOC Emissions
Fuelwood Utilization (Source Group 21)	20
Savanna Burning (Source Group 28)	16
Gasoline Storage, Consumption, Transportation, and Marketing (Source Group 4)	16
Refuse Disposal/Other (Source Group 22)	8
Miscellaneous Emission Sources (Source Group 27)	7
Rubber, Plastics, and Other Organic Chemical Manufacturing (Source Group 11)	7
Solvent Use (Source Group 12)	7
Deforestation for Agriculture (Source Group 23)	3
Total	84

Finally, it should be emphasized that over one half of the VOC emissions in the inventory can be attributed to the first three Source Groups listed above. As a result, the accuracy and reliability of the inventory is considered to be very sensitive to the assumptions and data used in developing the emissions estimates for those three groups.

Global distributions of emissions of the seven reactivity classes are shown in Figures 2 through 8. Figure 9 gives the distribution for the total VOC emissions. The three largest Source Groups and their contribution, in percentage of total emissions, to each reactivity class are shown below to assist in interpretation of the figures:

Paraffins
- Gasoline: Storage, Consumption, Transportation, and Marketing - 20%
- Fuelwood Utilization - 17%
- Solvent Use - 13%

Olefins
- Savanna Burning - 43%
- Fuelwood Utilization - 18%
- Refuse Disposal/Other - 9%

Aromatics
- Fuelwood Utilization - 49%
- Gasoline: Storage, Consumption, Transportation, and Marketing - 18%
- Miscellaneous Emission Sources - 11%

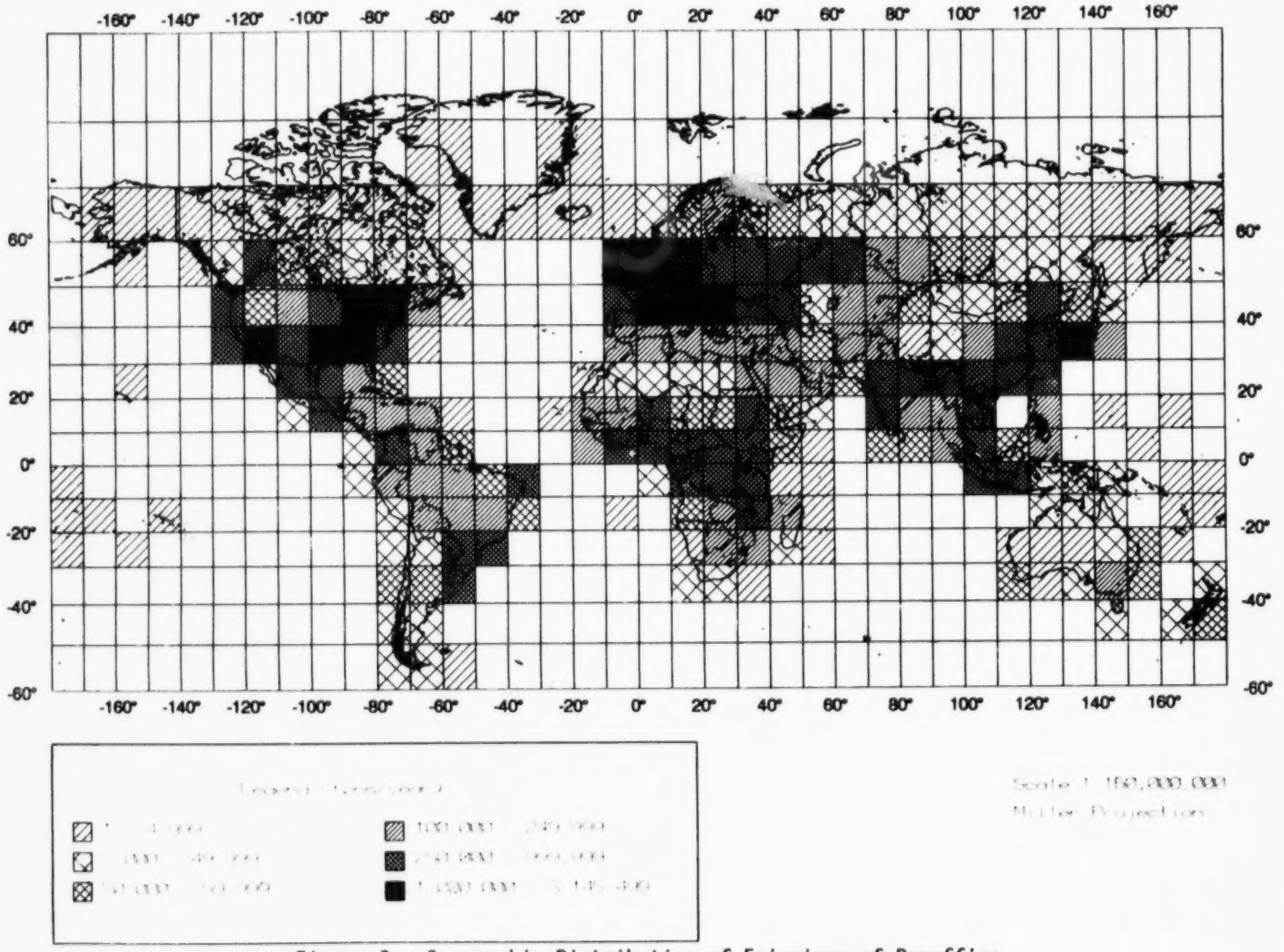

Figure 2. Geographic Distribution of Emissions of Paraffins

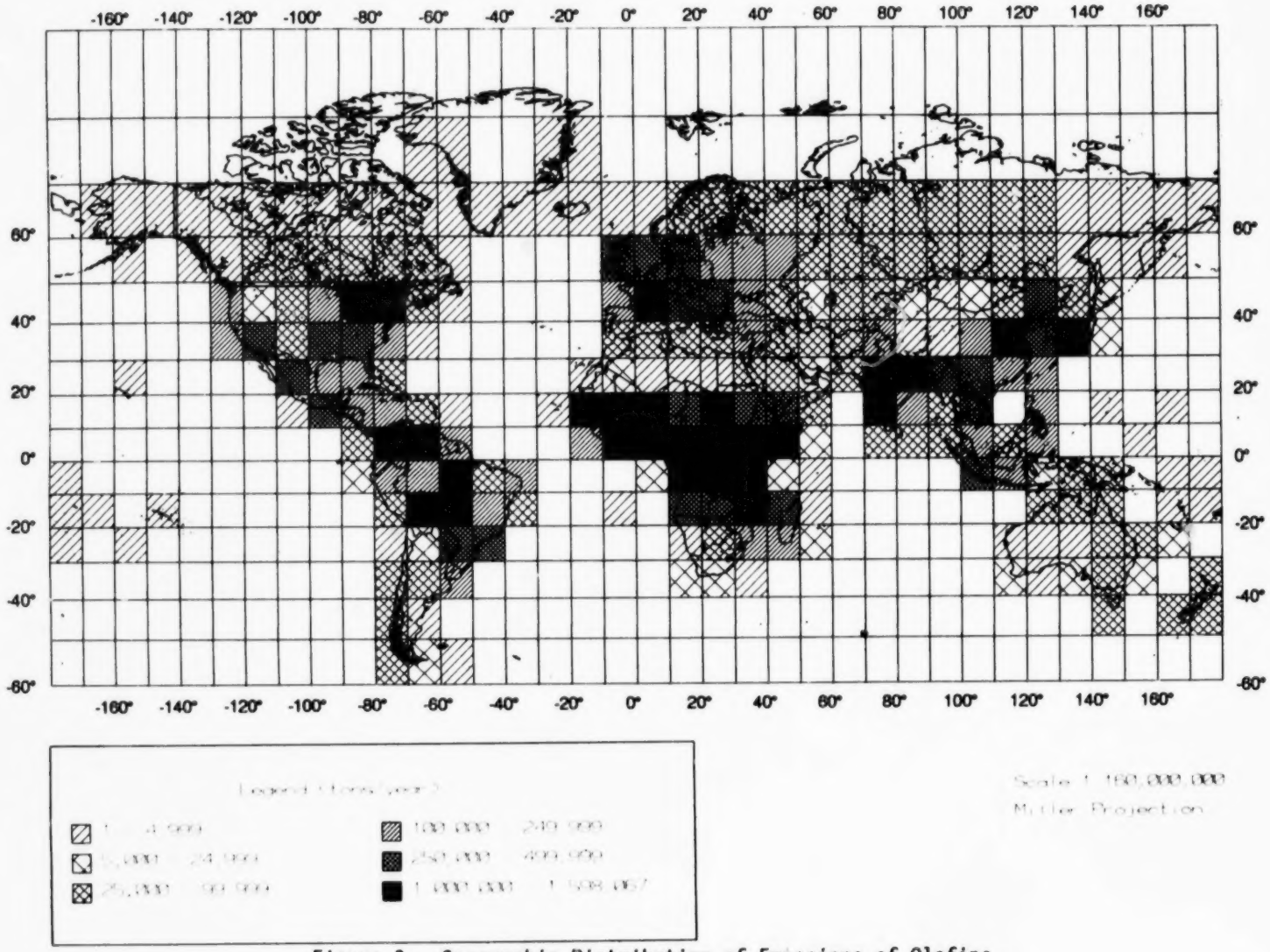

Figure 3. Geographic Distribution of Emissions of Olefins

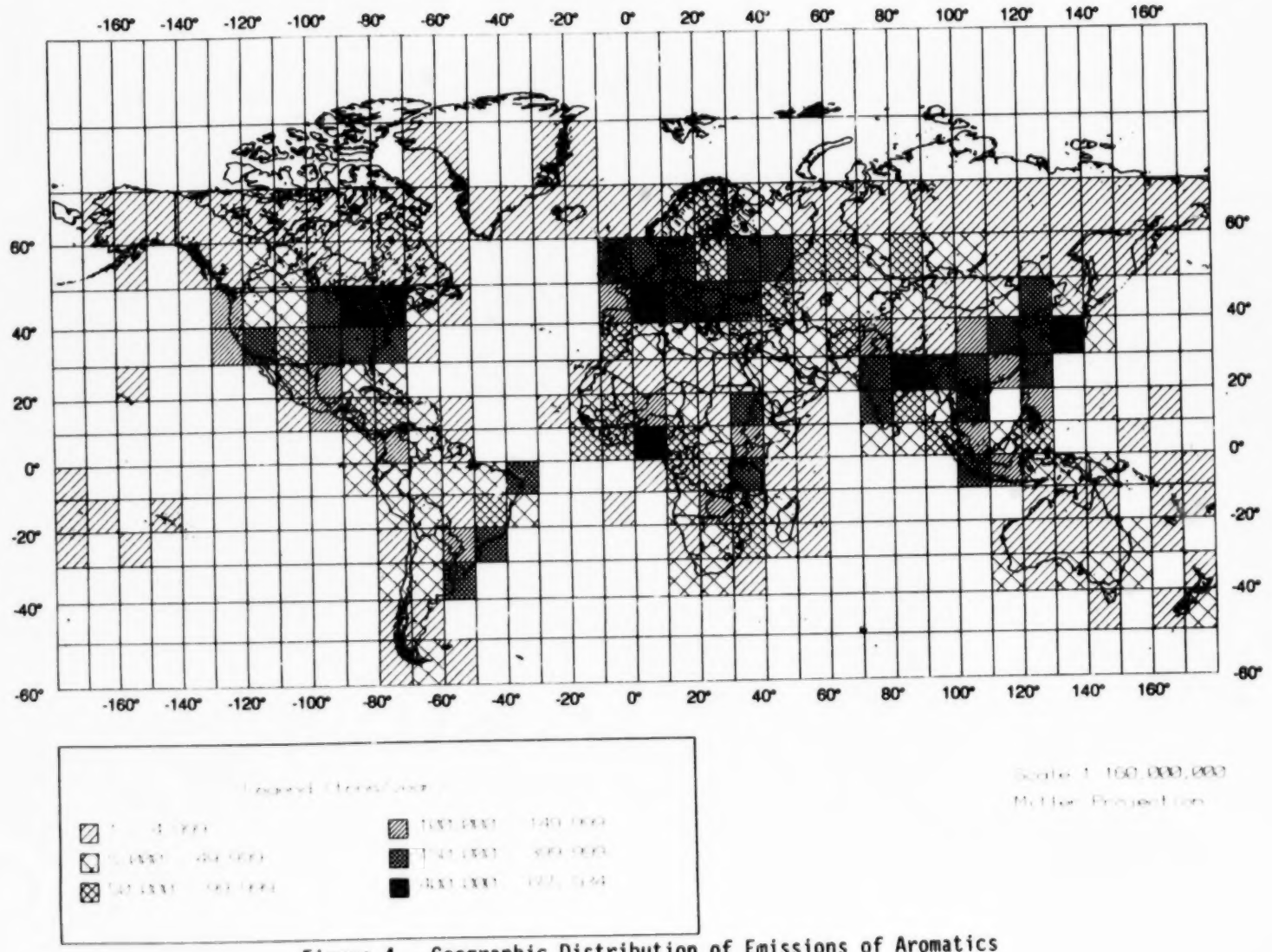

Figure 4. Geographic Distribution of Emissions of Aromatics

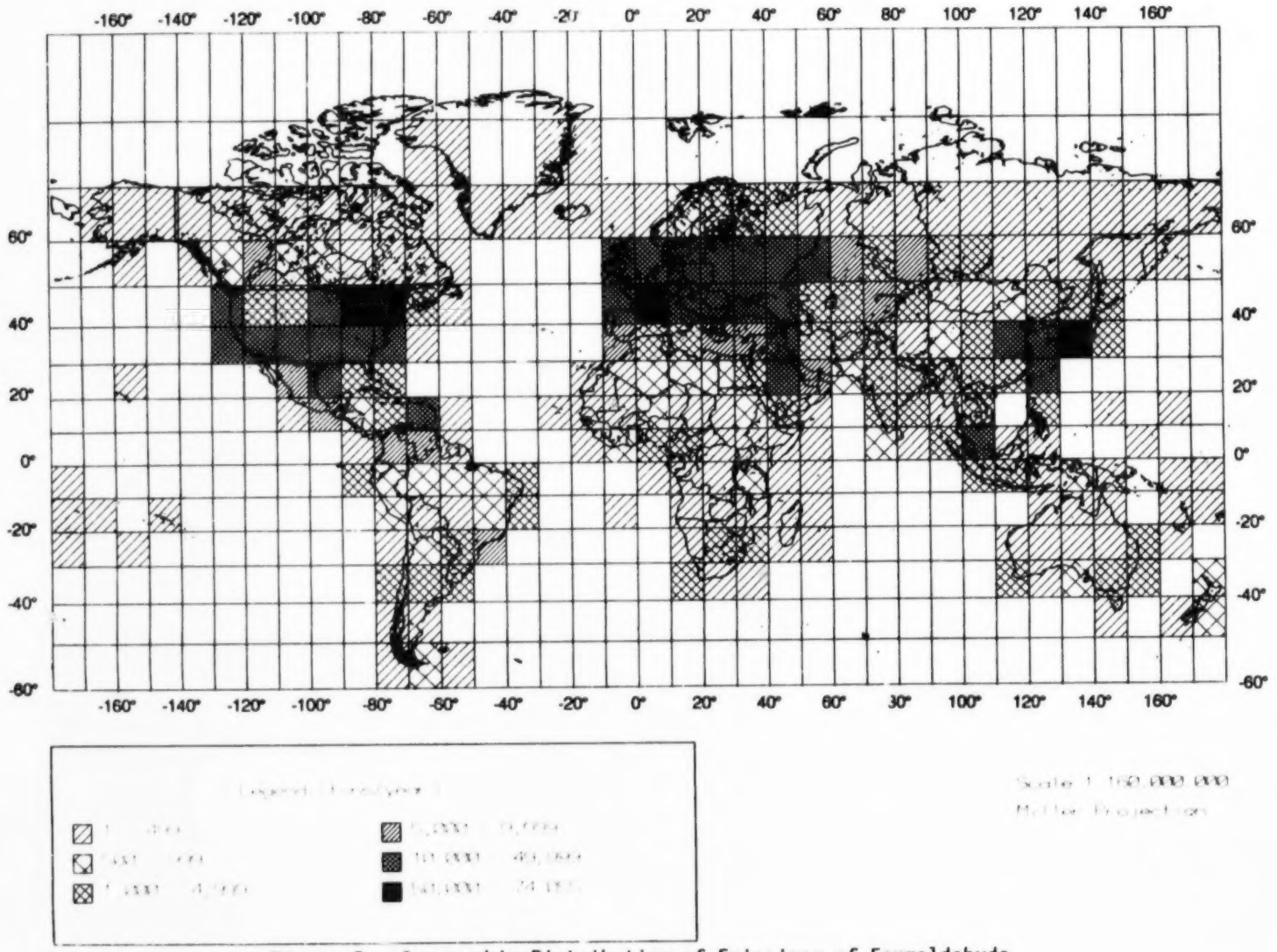

Figure 5. Geographic Distribution of Emissions of Formaldehyde

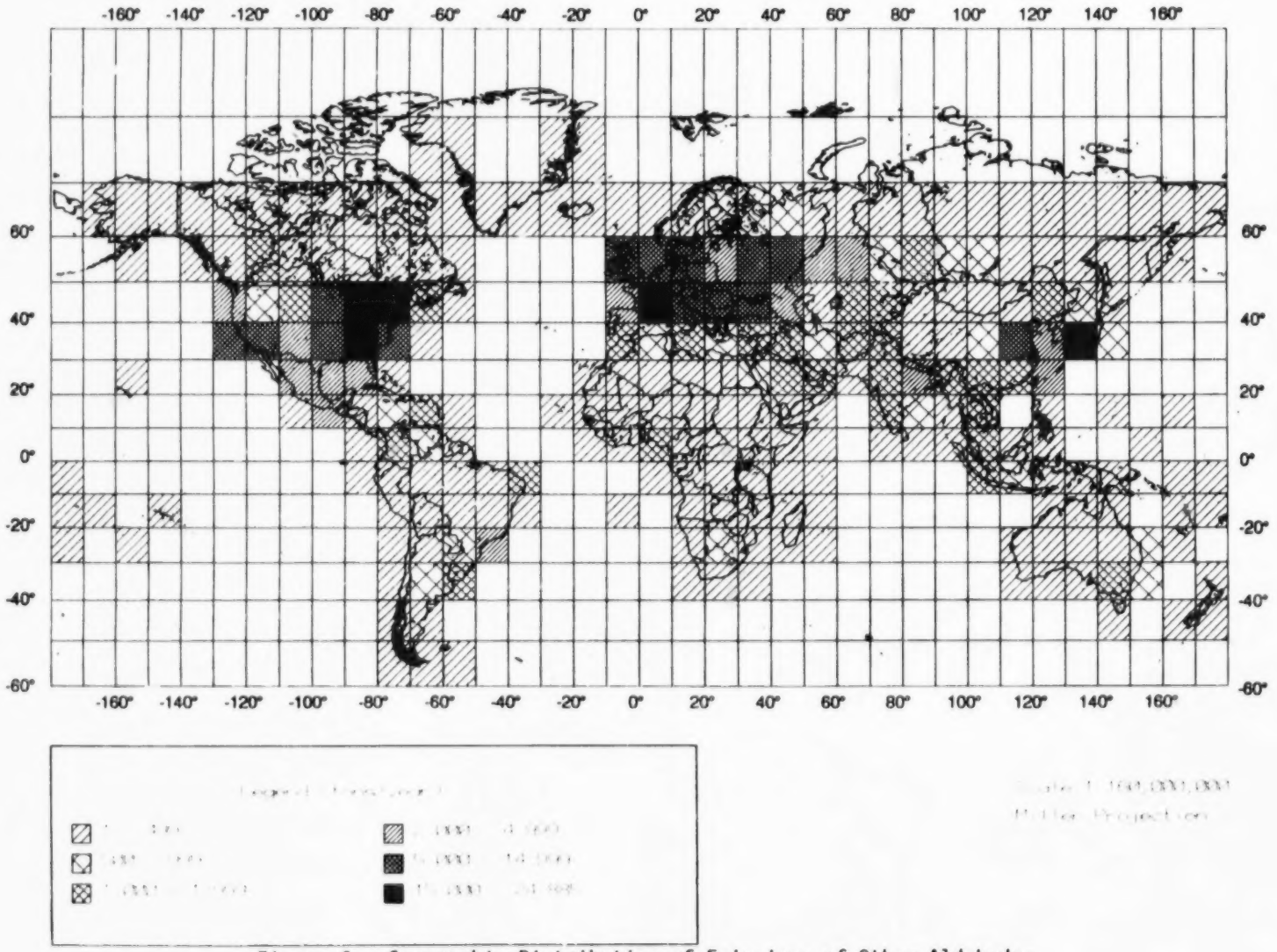

Figure 6. Geographic Distribution of Emissions of Other Aldehydes

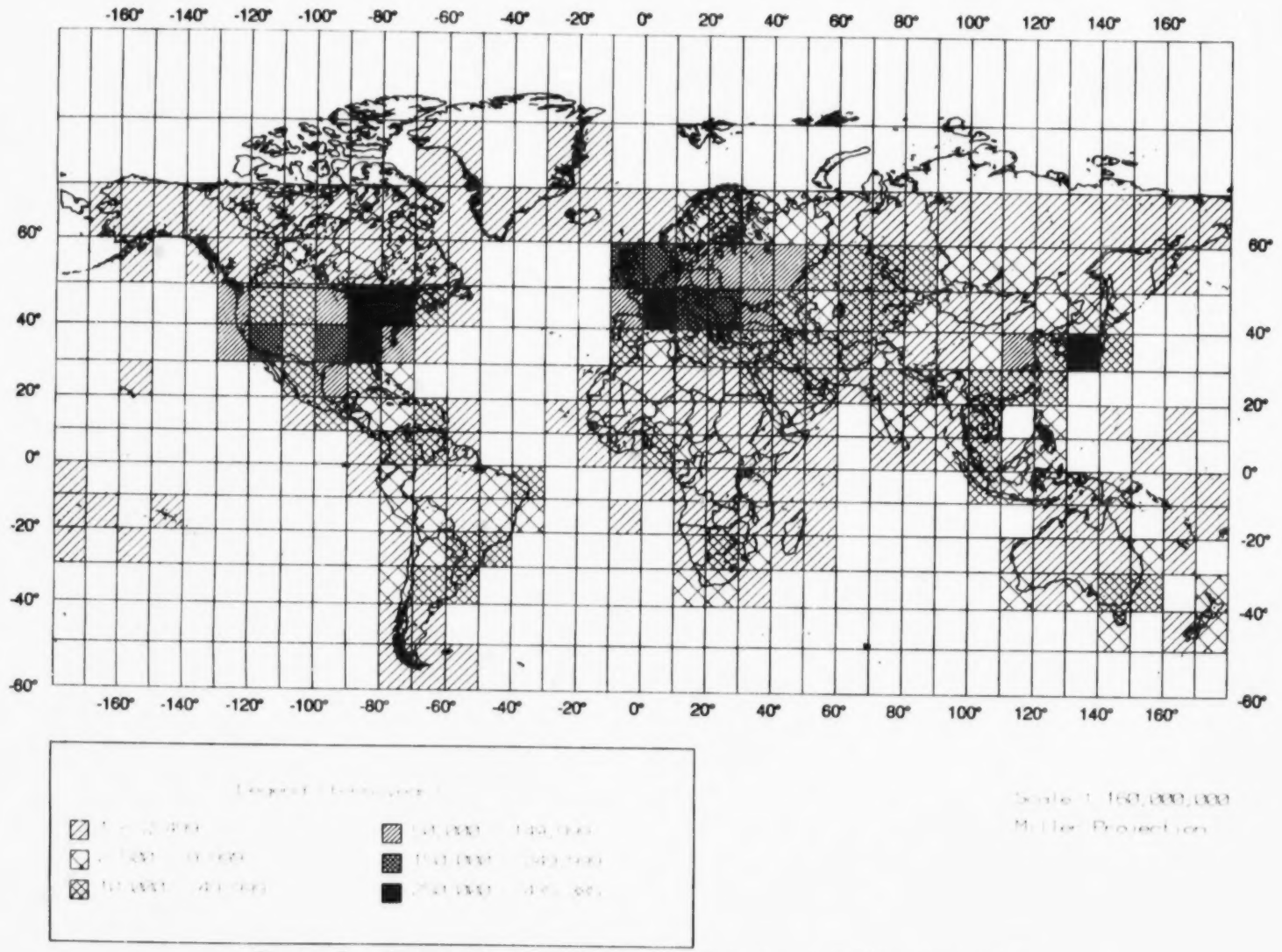

Figure 7. Geographic Distribution of Emissions of Other Aromatics

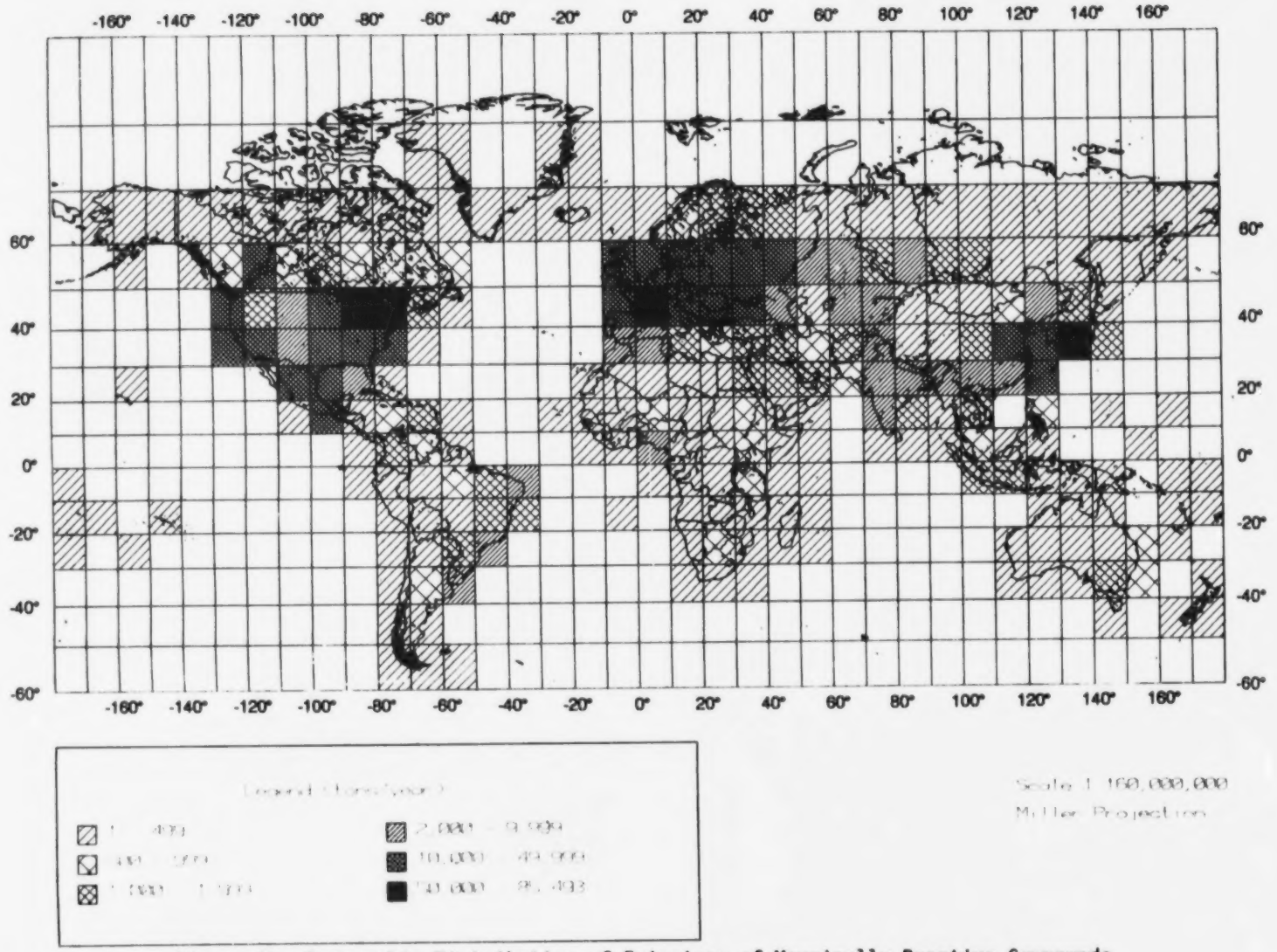

Figure 8. Geographic Distribution of Emissions of Marginally Reactive Compounds

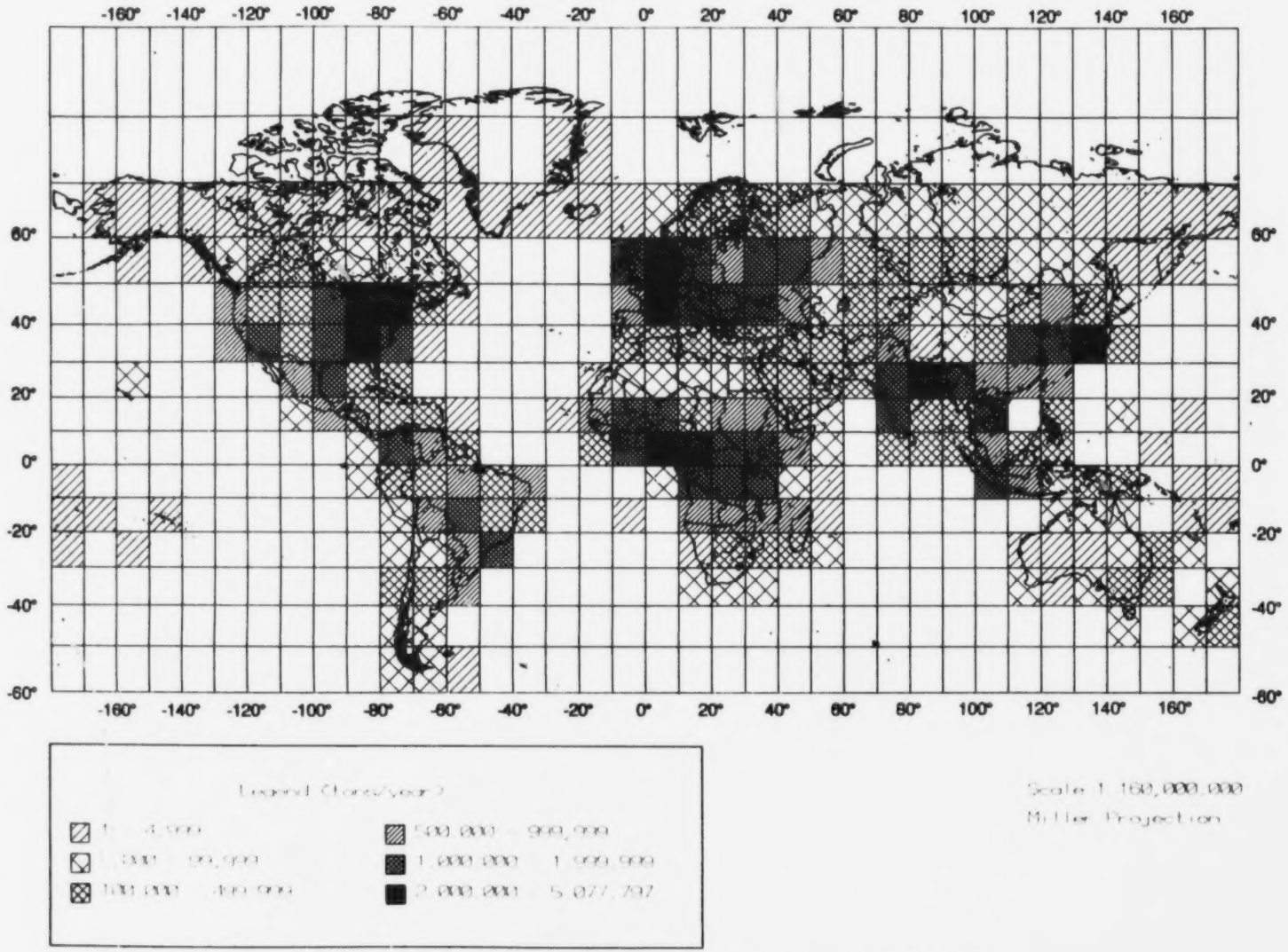

Figure 9. Geographic Distribution of Total VOC Emissions

Formaldehyde
Petroleum Refining - 44%
Gasoline: Storage, Consumption, Transportation, and Marketing - 12%
Diesel Vehicles - 11%

Other Aldehydes
Rubber, Plastics, and Other Organic Chemical Manufacturing - 24%
Diesel Vehicles - 19%
Miscellaneous Emission Sources - 16%

Other Aromatics
Gasoline: Storage, Consumption, Transportation, and Marketing - 56%
Rubber, Plastics, and Other Organic Chemical Manufacturing - 16%
Miscellaneous Emission Sources - 7%

Marginally Reactive Compounds
Solvent Use - 42%
Rubber, Plastics, and Other Organic Chemical Manufacturing - 19%
Miscellaneous Emission Sources - 13%

Fuelwood utilization is one of the largest Source Groups for emissions of olefins and aromatics. This accounts for the heavy emission rates of these VOCs from Africa and Asia. Savanna burning is the most significant source of olefin emissions and accounts for most of the high olefin emissions occurring in central Africa and South America. Fuelwood utilization also contributes significantly to olefin emissions in these areas.

The high rates of emissions of paraffins, olefins and aromatics in the industrialized areas of Europe and North America, as shown in Figures 2 through 4, are due to large contributions from the gasoline, solvent use, refuse disposal/other, and miscellaneous emission sources Source Groups. The "other aldehydes" reactivity class is primarily emitted by industrial sources such as diesel vehicles, chemical manufacturing and gasoline. For this reason, Figure 5 shows high rates of other aldehydes emissions to be limited to the heavily industrialized areas of the U.S., Japan and Europe. The distribution of formaldehyde emissions is heavily influenced by petroleum refining. Consequently, the areas of heavy formaldehyde emissions include the Middle East as well as the industrialized areas, as shown in Figure 6. The geographic distributions of other aromatics and marginally reactive compounds, as shown in Figures 7 and 8, generally cover the industrialized countries.

The Netherlands Organization for Applied Scientific Research (OASR) recently completed a global inventory of 11 volatile organic compounds (C. Veldt, 1988). Their study estimated that global emissions of the 11 specific VOCs were 66,700,000 tons per year. This report also estimated that total non-methane VOC emissions are roughly twice the estimate for the 11 specified compounds or 133,342,000 tons per year. The estimate presented in this report is about 10 percent below the estimate developed in the OASR study. No attempt was made to identify and evaluate the reasons for the difference between the two studies. However, given all the data uncertainties, they are still in reasonable agreement.

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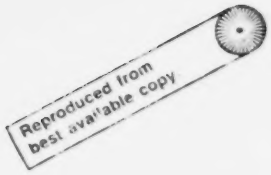
APPENDIX

GLOBAL VOC INVENTORY --
EMISSIONS ALLOCATED TO 10° X 10° GRID CELLS



GLOBAL VOC INVENTORY: EMISSIONS IN TONS/YEAR

GRID	LAT	LONG	PARAFFINS	OLEFINS	AROMATICS	FORMALDEHYDE	OTHER ALDEHYDES	OTHER AROMATICS	MARGINALLY REACTIVE	TOTAL VOC
0			0	0	0	0	0	0	0	0
1	85 N	175 E	0	0	0	0	0	0	0	0
2	75 N	175 E	0	0	0	0	0	0	0	0
3	65 N	175 E	850	279	174	21	10	212	10	1,557
4	55 N	175 E	0	0	0	0	0	0	0	0
5	45 N	175 E	0	0	0	0	0	0	0	0
6	35 N	175 E	0	0	0	0	0	0	0	0
7	25 N	175 E	0	0	0	0	0	0	0	0
8	15 N	175 E	0	0	0	0	0	0	0	0
9	5 N	175 E	0	0	0	0	0	0	0	0
10	5 S	175 E	7	7	1	0	0	0	0	16
11	15 S	175 E	1,854	949	606	23	13	257	22	3,725
12	25 S	175 E	0	0	0	0	0	0	0	0
13	35 S	175 E	46,166	39,664	4,382	522	189	3,699	166	95,287
14	45 S	175 E	53,555	40,620	8,348	949	272	4,584	272	108,606
15	55 S	175 E	0	0	0	0	0	0	0	0
16	65 S	175 E	0	0	0	0	0	0	0	0
17	75 S	175 E	0	0	0	0	0	0	0	0
18	85 S	175 E	0	0	0	0	0	0	0	0
19	85 N	165 E	0	0	0	0	0	0	0	0
20	75 N	165 E	0	0	0	0	0	0	0	0
21	65 N	165 E	850	279	174	21	10	212	10	1,557
22	55 N	165 E	1,701	558	349	42	20	424	21	3,114
23	45 N	165 E	0	0	0	0	0	0	0	0
24	35 N	165 E	0	0	0	0	0	0	0	0
25	25 N	165 E	0	0	0	0	0	0	0	0
26	15 N	165 E	0	0	0	0	0	0	0	1
27	5 N	165 E	0	0	0	0	0	0	0	0
28	5 S	165 E	1,866	1,544	1,227	7	4	72	7	4,748
29	15 S	165 E	365	269	166	3	2	27	3	835
30	25 S	165 E	1,793	7,435	247	35	16	240	10	9,776
31	35 S	165 E	0	0	0	0	0	0	0	0
32	45 S	165 E	35,436	37,263	1,574	154	73	1,628	56	76,186
33	55 S	165 E	0	0	0	0	0	0	0	0
34	65 S	165 E	0	0	0	0	0	0	0	0
35	75 S	165 E	0	0	0	0	0	0	0	0
36	85 S	165 E	0	0	0	0	0	0	0	0
37	85 N	155 E	0	0	0	0	0	0	0	0
38	75 N	155 E	0	0	0	0	0	0	0	0
39	65 N	155 E	850	279	174	21	10	212	10	1,557
40	55 N	155 E	2,875	883	752	65	32	496	67	5,169
41	45 N	155 E	0	0	0	0	0	0	0	0
42	35 N	155 E	0	0	0	0	0	0	0	0
43	25 N	155 E	0	0	0	0	0	0	0	0
44	15 N	155 E	0	0	0	0	0	0	0	0
45	5 N	155 E	415	191	85	7	4	73	5	771
46	5 S	155 E	0	0	0	0	0	0	0	0
47	15 S	155 E	0	0	0	0	0	0	0	0
48	25 S	155 E	50,416	31,646	14,877	1,061	575	9,908	609	109,091
49	35 S	155 E	75,183	21,903	22,123	1,662	865	15,674	861	138,276
50	45 S	155 E	0	0	0	0	0	0	0	0
51	55 S	155 E	0	0	0	0	0	0	0	0

GLOBAL VOC INVENTORY: EMISSIONS IN TONS/YEAR

GRID	LAT	LONG	PARAFFINS	OLEFINS	AROMATICS	FORMAL-DEHYDE	OTHER ALDEHYDES	OTHER AROMATICS	MARGINALLY REACTIVE	TOTAL VOC
52	65 S	155 E	0	0	0	0	0	0	0	0
53	75 S	155 E	0	0	0	0	0	0	0	0
54	85 S	155 E	0	0	0	0	0	0	0	0
55	85 N	145 E	0	0	0	0	0	0	0	0
56	75 N	145 E	0	0	0	0	0	0	0	0
57	65 N	145 E	850	279	174	21	10	212	10	1,557
58	55 N	145 E	405	121	116	9	4	57	11	723
59	45 N	145 E	27,156	5,531	3,648	1,847	190	3,760	229	42,350
60	35 N	145 E	102,283	23,046	15,958	4,446	765	15,992	1,491	163,980
61	25 N	145 E	0	0	0	0	0	0	0	0
62	15 N	145 E	3,318	560	461	289	34	412	13	5,087
63	5 N	145 E	0	0	0	0	0	0	0	0
64	5 S	145 E	44,346	65,936	30,174	97	56	553	89	141,251
65	15 S	145 E	32,114	49,964	546	54	25	547	21	83,270
66	25 S	145 E	12,746	73,500	1,310	132	62	1,358	52	89,160
67	35 S	145 E	139,097	61,849	26,773	4,412	1,030	18,712	1,015	252,888
68	45 S	145 E	40,027	38,276	2,585	263	123	2,709	103	84,086
69	55 S	145 E	0	0	0	0	0	0	0	0
70	65 S	145 E	0	0	0	0	0	0	0	0
71	75 S	145 E	0	0	0	0	0	0	0	0
72	85 S	145 E	0	0	0	0	0	0	0	0
73	85 N	135 E	0	0	0	0	0	0	0	0
74	75 N	135 E	0	0	0	0	0	0	0	0
75	65 N	135 E	850	279	174	21	10	212	10	1,557
76	55 N	135 E	9,678	3,114	2,147	231	112	2,191	151	17,624
77	45 N	135 E	68,176	27,158	17,613	1,776	665	8,917	1,512	125,816
78	35 N	135 E	2,607,400	502,307	474,366	57,302	21,204	332,726	85,494	4,080,899
79	25 N	135 E	0	0	0	0	0	0	0	0
80	15 N	135 E	0	0	0	0	0	0	0	0
81	5 N	135 E	0	0	0	0	0	0	0	0
82	5 S	135 E	65,382	53,030	45,840	718	33	192	39	165,234
83	15 S	135 E	30,252	49,339	138	12	6	114	5	79,915
84	25 S	135 E	749	199	189	17	8	168	7	1,336
85	35 S	135 E	35,044	10,765	10,896	748	422	6,965	475	65,315
86	45 S	135 E	0	0	0	0	0	0	0	0
87	55 S	135 E	0	0	0	0	0	0	0	0
88	65 S	135 E	0	0	0	0	0	0	0	0
89	75 S	135 E	0	0	0	0	0	0	0	0
90	85 S	135 E	0	0	0	0	0	0	0	0
91	85 N	125 E	0	0	0	0	0	0	0	0
92	75 N	125 E	0	0	0	0	0	0	0	0
93	65 N	125 E	29,252	35,622	174	21	10	212	10	65,301
94	55 N	125 E	40,426	39,696	2,741	271	135	2,358	221	85,850
95	45 N	125 E	381,530	314,076	208,550	2,290	1,240	9,639	2,114	921,438
96	35 N	125 E	693,577	392,961	252,613	1,241	4,006	42,343	13,290	1,400,232
97	25 N	125 E	531,234	223,259	190,546	1,354	3,709	42,892	19,791	1,121,815
98	15 N	125 E	221,690	196,521	118,075	2,151	431	4,232	707	541,804
99	5 N	125 E	118,357	113,785	51,186	464	270	2,675	445	287,181
100	5 S	125 E	18,638	14,756	8,521	169	102	1,070	171	43,237
101	15 S	125 E	30,349	58,519	51	5	2	54	2	89,483
102	25 S	125 E	749	199	189	17	8	168	7	1,336
103	35 S	125 E	286	82	87	7	3	60	3	527

GLOBAL VOC INVENTORY: EMISSIONS IN TONS/YEAR

GRID	LAT	LONG	PARAFFINS	OLEFINS	AROMATICS	FORMALDEHYDE	OTHER ALDEHYDES	OTHER AROMATICS	MARGINALLY REACTIVE	TOTAL VOC
104	45 S	125 E	0	0	0	0	0	0	0	0
105	55 S	125 E	0	0	0	0	0	0	0	0
106	65 S	125 E	0	0	0	0	0	0	0	0
107	75 S	125 E	0	0	0	0	0	0	0	0
108	85 S	125 E	0	0	0	0	0	0	0	0
109	85 N	115 E	0	0	0	0	0	0	0	0
110	75 N	115 E	0	0	0	0	0	0	0	0
111	65 N	115 E	29,252	35,622	174	21	10	212	10	65,301
112	55 N	115 E	46,584	41,245	3,890	439	213	4,310	255	96,936
113	45 N	115 E	52,643	40,824	23,531	801	270	2,213	518	120,839
114	35 N	115 E	952,528	760,157	331,251	12,247	6,304	51,651	12,896	2,127,033
115	25 N	115 E	296,089	243,438	116,835	3,462	1,549	12,847	3,031	677,251
116	15 N	115 E	0	0	0	0	0	0	0	0
117	5 N	115 E	83,077	80,216	34,073	460	112	762	107	198,808
118	5 S	115 E	238,853	248,665	144,664	2,279	845	3,496	1,387	695,190
119	15 S	115 E	0	0	0	0	0	0	0	0
120	25 S	115 E	1,320	363	362	30	15	288	13	2,391
121	35 S	115 E	53,562	10,039	9,416	3,107	389	6,701	446	83,660
122	45 S	115 E	0	0	0	0	0	0	0	0
123	55 S	115 E	0	0	0	0	0	0	0	0
124	65 S	115 E	0	0	0	0	0	0	0	0
125	75 S	115 E	0	0	0	0	0	0	0	0
126	85 S	115 E	0	0	0	0	0	0	0	0
127	85 N	105 E	0	0	0	0	0	0	0	0
128	75 N	105 E	0	0	0	0	0	0	0	0
129	65 N	105 E	29,252	35,622	174	21	10	212	10	65,301
130	55 N	105 E	90,862	49,986	12,750	2,669	518	6,596	1,342	164,723
131	45 N	105 E	8,965	6,324	4,473	81	45	744	66	20,698
132	35 N	105 E	138,391	153,830	103,831	1,961	807	6,026	1,506	456,251
133	25 N	105 E	400,739	351,620	201,849	2,499	1,605	12,221	3,319	974,052
134	15 N	105 E	478,990	419,172	259,353	3,433	1,215	10,578	1,864	1,204,605
135	5 N	105 E	278,865	170,322	101,529	11,005	1,171	16,167	735	579,794
136	5 S	105 E	551,953	480,790	342,034	3,271	1,047	10,019	1,652	1,390,816
137	15 S	105 E	0	0	0	0	0	0	0	0
138	25 S	105 E	0	0	0	0	0	0	0	0
139	35 S	105 E	0	0	0	0	0	0	0	0
140	45 S	105 E	0	0	0	0	0	0	0	0
141	55 S	105 E	0	0	0	0	0	0	0	0
142	65 S	105 E	0	0	0	0	0	0	0	0
143	75 S	105 E	0	0	0	0	0	0	0	0
144	85 S	105 E	0	0	0	0	0	0	0	0
145	85 N	95 E	0	0	0	0	0	0	0	0
146	75 N	95 E	0	0	0	0	0	0	0	0
147	65 N	95 E	29,252	35,622	174	21	10	212	10	65,301
148	55 N	95 E	90,862	49,986	12,750	2,669	518	6,596	1,342	164,723
149	45 N	95 E	5,535	3,915	2,562	54	31	471	48	12,616
150	35 N	95 E	8,376	1,083	304	847	13	109	29	11,261
151	25 N	95 E	432,932	428,317	245,421	4,171	1,509	8,697	3,488	1,174,735
152	15 N	95 E	100,235	79,662	40,862	404	176	1,258	349	242,916
153	5 N	95 E	111,312	59,766	69,180	1,153	277	2,663	397	274,749
154	5 S	95 E	0	0	0	0	0	0	0	0
155	15 S	95 E	0	0	0	0	0	0	0	0

GLOBAL VOC INVENTORY: EMISSIONS IN TONS/YEAR

GRID	LAT	LONG	PARAFFINS	OLEFINS	AROMATICS	FORMALDEHYDE	OTHER ALDEHYDES	OTHER AROMATICS	MARGINALLY REACTIVE	TOTAL VOC
156	25 S	95 E	0	0	0	0	0	0	0	0
157	35 S	95 E	0	0	0	0	0	0	0	0
158	45 S	95 E	0	0	0	0	0	0	0	0
159	55 S	95 E	0	0	0	0	0	0	0	0
160	65 S	95 E	0	0	0	0	0	0	0	0
161	75 S	95 E	0	0	0	0	0	0	0	0
162	85 S	95 E	0	0	0	0	0	0	0	0
163	85 N	85 E	0	0	0	0	0	0	0	0
164	75 N	85 E	0	0	0	0	0	0	0	0
165	65 N	85 E	30,102	35,901	349	42	20	424	21	66,958
166	55 N	85 E	218,024	86,629	51,562	5,355	1,830	20,778	5,479	389,657
167	45 N	85 E	52,691	23,879	14,303	2,378	259	3,324	462	97,297
168	35 N	85 E	1,173	914	191	17	11	96	24	2,426
169	25 N	85 E	933,058	834,297	499,775	4,463	2,949	17,524	7,158	2,299,144
170	15 N	85 E	158,203	130,605	70,239	2,072	632	3,799	1,542	367,093
171	5 N	85 E	73,363	76,363	45,025	498	142	1,300	317	197,030
172	5 S	85 E	0	0	0	0	0	0	0	0
173	15 S	85 E	0	0	0	0	0	0	0	0
174	25 S	85 E	0	0	0	0	0	0	0	0
175	35 S	85 E	0	0	0	0	0	0	0	0
176	45 S	85 E	0	0	0	0	0	0	0	0
177	55 S	85 E	0	0	0	0	0	0	0	0
178	65 S	85 E	0	0	0	0	0	0	0	0
179	75 S	85 E	0	0	0	0	0	0	0	0
180	85 S	85 E	0	0	0	0	0	0	0	0
181	85 N	75 E	0	0	0	0	0	0	0	0
182	75 N	75 E	0	0	0	0	0	0	0	0
183	65 N	75 E	29,252	35,622	174	21	10	212	10	65,301
184	55 N	75 E	117,716	56,040	16,198	3,970	759	11,201	1,646	207,529
185	45 N	75 E	141,516	38,341	26,850	5,233	1,376	24,009	2,296	239,621
186	35 N	75 E	239,343	200,343	126,204	2,272	1,048	7,393	2,135	578,738
187	25 N	75 E	701,396	634,491	395,135	3,410	1,813	11,060	4,695	1,752,500
188	15 N	75 E	546,873	503,281	315,144	2,535	1,160	7,071	3,207	1,379,290
189	5 N	75 E	61,681	50,038	32,489	841	171	1,049	442	146,712
190	5 S	75 E	0	0	0	0	0	0	0	0
191	15 S	75 E	0	0	0	0	0	0	0	0
192	25 S	75 E	0	0	0	0	0	0	0	0
193	35 S	75 E	0	0	0	0	0	0	0	0
194	45 S	75 E	0	0	0	0	0	0	0	0
195	55 S	75 E	0	0	0	0	0	0	0	0
196	65 S	75 E	0	0	0	0	0	0	0	0
197	75 S	75 E	0	0	0	0	0	0	0	0
198	85 S	75 E	0	0	0	0	0	0	0	0
199	65 N	65 E	0	0	0	0	0	0	0	0
200	75 N	65 E	0	0	0	0	0	0	0	0
201	65 N	65 E	36,906	38,131	1,743	208	101	2,119	104	79,312
202	55 N	65 E	254,370	93,630	67,308	5,394	2,243	23,733	7,241	453,419
203	45 N	65 E	125,596	36,332	30,465	3,484	1,306	20,262	2,796	220,241
204	35 N	65 E	137,408	77,777	50,629	2,293	1,079	19,273	1,498	289,959
205	25 N	65 E	71,015	60,009	37,174	679	340	2,250	659	172,126
206	15 N	65 E	0	0	0	0	0	0	0	0
207	5 N	65 E	0	0	0	0	0	0	0	0

GLOBAL VOC INVENTORY: EMISSIONS IN TONS/YEAR

GRID	LAT	LONG	PARAFFINS	OLEFINS	AROMATICS	FORMAL-DEHYDE	OTHER ALDEHYDES	OTHER AROMATICS	MARGINALLY REACTIVE	TOTAL VOC
208	5 S	65 E	0	0	0	0	0	0	0	0
209	15 S	65 E	0	0	0	0	0	0	0	0
210	25 S	65 E	0	0	0	0	0	0	0	0
211	35 S	65 E	0	0	0	0	0	0	0	0
212	45 S	65 E	0	0	0	0	0	0	0	0
213	55 S	65 E	0	0	0	0	0	0	0	0
214	65 S	65 E	0	0	0	0	0	0	0	0
215	75 S	65 E	0	0	0	0	0	0	0	0
216	85 S	65 E	0	0	0	0	0	0	0	0
217	85 N	55 E	0	0	0	0	0	0	0	0
218	75 N	55 E	0	0	0	0	0	0	0	0
219	65 N	55 E	0	0	0	0	0	0	0	0
220	55 N	55 E	47,114	41,296	3,910	483	215	4,331	260	97,610
221	45 N	55 E	497,541	93,156	80,059	27,197	3,460	37,744	9,834	748,990
222	35 N	55 E	32,066	5,463	3,322	2,037	208	3,119	396	46,611
223	25 N	55 E	72,094	29,497	16,886	2,009	702	12,093	754	134,037
224	15 N	55 E	157,101	23,654	18,730	8,823	1,448	15,594	1,412	226,762
225	5 N	55 E	6,717	31,091	2,551	27	14	197	15	40,611
226	5 S	55 E	976	9,203	17	2	1	10	2	10,212
227	15 S	55 E	241	93	69	5	2	43	3	456
228	25 S	55 E	57	42	10	1	1	5	1	117
229	35 S	55 E	4,715	6,898	1,066	87	44	652	51	13,513
230	45 S	55 E	0	0	0	0	0	0	0	0
231	55 S	55 E	0	0	0	0	0	0	0	0
232	65 S	55 E	0	0	0	0	0	0	0	0
233	75 S	55 E	0	0	0	0	0	0	0	0
234	85 S	55 E	0	0	0	0	0	0	0	0
235	85 N	45 E	0	0	0	0	0	0	0	0
236	75 N	45 E	0	0	0	0	0	0	0	0
237	65 N	45 E	0	0	0	0	0	0	0	0
238	55 N	45 E	77,391	50,215	13,296	1,089	531	7,798	1,244	151,563
239	45 N	45 E	827,122	236,420	201,978	26,825	7,211	77,632	22,194	1,399,382
240	35 N	45 E	372,253	95,056	84,666	13,357	3,393	43,750	8,829	621,293
241	25 N	45 E	226,481	71,437	44,374	10,521	1,300	21,241	1,577	376,930
242	15 N	45 E	192,591	72,480	22,759	10,954	1,220	24,225	1,003	331,233
243	5 N	45 E	76,622	313,962	19,461	1,234	276	5,456	328	416,338
244	5 S	45 E	97,165	716,755	19,852	163	87	659	173	833,853
245	15 S	45 E	4,014	11,901	2,300	5	3	26	5	18,313
246	25 S	45 E	199,363	410,435	28,623	210	117	1,067	260	640,096
247	35 S	45 E	27,627	120,008	11,013	67	45	454	96	159,310
248	45 S	45 E	0	0	0	0	0	0	0	0
249	55 S	45 E	0	0	0	0	0	0	0	0
250	65 S	45 E	0	0	0	0	0	0	0	0
251	75 S	45 E	0	0	0	0	0	0	0	0
252	85 S	45 E	0	0	0	0	0	0	0	0
253	85 N	35 E	0	0	0	0	0	0	0	0
254	75 N	35 E	0	0	0	0	0	0	0	0
255	65 N	35 E	0	0	0	0	0	0	0	0
256	55 N	35 E	77,922	50,265	13,316	1,173	533	7,819	1,249	152,237
257	45 N	35 E	774,089	231,559	200,047	22,370	7,300	75,492	21,697	1,332,053
258	35 N	35 E	774,538	221,763	196,699	25,859	6,324	83,793	18,560	1,326,036
259	25 N	35 E	212,135	121,103	54,737	5,930	1,169	20,670	1,738	417,482
260	15 N	35 E	119,123	51,335	19,969	4,091	883	17,125	1,028	212,558

GLOBAL VOC INVENTORY: EMISSIONS IN TONS/YEAR

GRID	LAT	LONG	PARAFFINS	OLEFINS	AROMATICS	FORMALDEHYDE	OTHER ALDEHYDES	OTHER AROMATICS	MARGINALLY REACTIVE	TOTAL VOC
260	15 N	35 E	291,064	398,581	203,266	542	249	1,840	547	896,091
261	5 N	35 E	316,175	1,324,346	146,362	363	263	1,728	576	1,789,812
262	5 S	35 E	551,933	859,760	383,699	862	299	2,211	609	1,804,374
263	15 S	35 E	271,429	560,807	74,278	279	196	1,679	422	909,092
264	25 S	35 E	115,812	216,224	59,306	1,459	287	5,370	390	398,849
265	35 S	35 E	4,360	1,677	917	87	44	860	44	7,989
266	45 S	35 E	0	0	0	0	0	0	0	0
267	55 S	35 E	0	0	0	0	0	0	0	0
268	65 S	35 E	0	0	0	0	0	0	0	0
269	75 S	35 E	0	0	0	0	0	0	0	0
270	85 S	35 E	0	0	0	0	0	0	0	0
271	85 N	25 E	0	0	0	0	0	0	0	0
272	75 N	25 E	0	0	0	0	0	0	0	0
273	65 N	25 E	163,756	78,894	50,124	4,642	949	17,600	1,709	317,675
274	55 N	25 E	470,890	150,858	93,423	14,450	3,991	52,399	11,615	797,625
275	45 N	25 E	1,276,823	351,605	250,665	32,031	10,531	153,469	37,083	2,112,206
276	35 N	25 E	120,649	47,035	32,420	5,699	691	10,572	853	217,919
277	25 N	25 E	17,563	3,213	3,951	720	99	1,008	122	26,675
278	15 N	25 E	56,636	561,700	488	41	28	220	62	619,176
279	5 N	25 E	293,144	1,432,470	27,002	120	86	629	190	1,753,642
280	5 S	25 E	341,317	1,159,937	83,125	293	209	1,461	479	1,586,810
281	15 S	25 E	172,712	300,045	118,647	277	107	1,123	205	593,115
282	25 S	25 E	106,850	54,132	48,679	1,999	514	11,367	676	222,216
283	35 S	25 E	39,862	19,930	17,783	489	244	5,350	305	83,963
284	45 S	25 E	0	0	0	0	0	0	0	0
285	55 S	25 E	0	0	0	0	0	0	0	0
286	65 S	25 E	0	0	0	0	0	0	0	0
287	75 S	25 E	0	0	0	0	0	0	0	0
288	85 S	25 E	0	0	0	0	0	0	0	0
289	85 N	15 E	0	0	0	0	0	0	0	0
290	75 N	15 E	0	0	0	0	0	0	0	0
291	65 N	15 E	61,292	44,324	6,767	737	342	5,510	680	119,652
292	55 N	15 E	1,214,070	293,890	247,322	27,400	9,022	134,842	36,451	1,961,987
293	45 N	15 E	1,226,145	324,775	244,524	23,286	9,476	155,687	33,942	2,022,835
294	35 N	15 E	114,029	43,357	29,730	2,388	1,051	20,159	1,412	212,126
295	25 N	15 E	16,994	2,768	3,858	712	93	964	110	25,500
296	15 N	15 E	52,532	406,111	8,969	69	42	574	69	468,366
297	5 N	15 E	372,738	1,593,067	64,646	1,075	290	4,312	442	2,041,621
298	5 S	15 E	334,782	1,197,910	75,792	453	128	1,055	265	1,610,388
299	15 S	15 E	72,827	452,253	21,440	104	67	596	138	547,424
300	25 S	15 E	763	294	160	15	8	151	8	1,399
301	35 S	15 E	41,176	17,968	16,730	1,346	189	4,267	248	81,922
302	45 S	15 E	0	0	0	0	0	0	0	0
303	55 S	15 E	0	0	0	0	0	0	0	0
304	65 S	15 E	0	0	0	0	0	0	0	0
305	75 S	15 E	0	0	0	0	0	0	0	0
306	85 S	15 E	0	0	0	0	0	0	0	0
307	85 N	5 E	0	0	0	0	0	0	0	0
308	75 N	5 E	0	0	0	0	0	0	0	0
309	65 N	5 E	15,632	2,428	3,391	454	65	1,217	348	23,536
310	55 N	5 E	1,539,424	355,224	289,444	46,097	13,153	210,221	45,034	2,598,597
311	45 N	5 E	2,131,203	505,413	413,127	50,113	16,551	263,472	61,519	3,441,398

GLOBAL VOC INVENTORY: EMISSIONS IN TONS/YEAR

GRID	LAT	LONG	PARAFFINS	OLEFINS	AROMATICS	FORMALDEHYDE	OTHER ALDEHYDES	OTHER AROMATICS	MARGINALLY REACTIVE	TOTAL VOC
312	35 N	5 E	118,091	34,905	29,023	4,254	575	9,147	2,054	198,049
313	25 N	5 E	11,093	1,215	511	953	22	342	32	14,168
314	15 N	5 E	292,885	1,106,921	143,820	599	368	3,871	542	1,549,006
315	5 N	5 E	824,547	1,240,629	406,008	3,818	1,492	18,314	2,124	2,497,233
316	5 S	5 E	9,966	13,829	4,276	238	13	178	18	28,538
317	15 S	5 E	0	0	0	0	0	0	0	0
318	25 S	5 E	0	0	0	0	0	0	0	0
319	35 S	5 E	0	0	0	0	0	0	0	0
320	45 S	5 E	0	0	0	0	0	0	0	0
321	55 S	5 E	0	0	0	0	0	0	0	0
322	65 S	5 E	0	0	0	0	0	0	0	0
323	75 S	5 E	0	0	0	0	0	0	0	0
324	85 S	5 E	0	0	0	0	0	0	0	0
325	85 N	5 W	0	0	0	0	0	0	0	0
326	75 N	5 W	0	0	0	0	0	0	0	0
327	65 N	5 W	319	96	71	6	3	69	3	567
328	55 N	5 W	1,062,206	255,585	206,886	23,953	9,208	157,549	21,824	1,742,811
329	45 N	5 W	530,177	158,416	100,817	14,892	4,077	70,008	11,588	889,975
330	35 N	5 W	238,644	80,849	51,970	6,251	1,859	30,145	5,332	415,050
331	25 N	5 W	7,112	5,413	3,162	63	38	503	64	16,354
332	15 N	5 W	149,496	1,212,274	54,147	192	139	1,089	307	1,457,645
333	5 N	5 W	333,098	1,014,893	84,825	841	235	2,335	416	1,436,643
334	5 S	5 W	0	0	0	0	0	0	0	0
335	15 S	5 W	13	12	6	0	0	0	0	31
336	25 S	5 W	0	0	0	0	0	0	0	0
337	35 S	5 W	0	0	0	0	0	0	0	0
338	45 S	5 W	0	0	0	0	0	0	0	0
339	55 S	5 W	0	0	0	0	0	0	0	0
340	65 S	5 W	0	0	0	0	0	0	0	0
341	75 S	5 W	0	0	0	0	0	0	0	0
342	85 S	5 W	0	0	0	0	0	0	0	0
343	85 N	15 W	0	0	0	0	0	0	0	0
344	75 N	15 W	4	1	1	0	0	1	0	7
345	65 N	15 W	293	93	54	10	4	63	3	531
346	55 N	15 W	0	0	0	0	0	0	0	0
347	45 N	15 W	0	0	0	0	0	0	0	0
348	35 N	15 W	0	0	0	0	0	0	0	0
349	25 N	15 W	1,101	721	217	16	10	123	19	2,206
350	15 N	15 W	127,734	773,772	37,365	246	123	1,299	243	945,772
351	5 N	15 W	103,912	193,340	62,652	261	74	717	157	367,114
352	5 S	15 W	0	0	0	0	0	0	0	0
353	15 S	15 W	0	0	0	0	0	0	0	0
354	25 S	15 W	0	0	0	0	0	0	0	0
355	35 S	15 W	0	0	0	0	0	0	0	0
356	45 S	15 W	0	0	0	0	0	0	0	0
357	55 S	15 W	0	0	0	0	0	0	0	0
358	65 S	15 W	0	0	0	0	0	0	0	0
359	75 S	15 W	0	0	0	0	0	0	0	0
360	85 S	15 W	0	0	0	0	0	0	0	0
361	85 N	25 W	0	0	0	0	0	0	0	0
362	75 N	25 W	11	4	2	0	0	2	0	20
363	65 N	25 W	1,694	539	372	53	26	366	17	3,075

GLOBAL VOC INVENTORY: EMISSIONS IN TONS/YEAR

GRID	LAT	LONG	PARAFFINS	OLEFINS	AROMATICS	FORMALDEHYDE	OTHER ALDEHYDES	OTHER AROMATICS	MARGINALLY REACTIVE	TOTAL VOC
364	55 N	25 W	0	0	0	0	0	0	0	0
365	45 N	25 W	0	0	0	0	0	0	0	0
366	35 N	25 W	0	0	0	0	0	0	0	0
367	25 N	25 W	0	0	0	0	0	0	0	0
368	15 N	25 W	406	306	79	5	3	31	7	837
369	5 N	25 W	0	0	0	0	0	0	0	0
370	5 S	25 W	0	0	0	0	0	0	0	0
371	15 S	25 W	0	0	0	0	0	0	0	0
372	25 S	25 W	0	0	0	0	0	0	0	0
373	35 S	25 W	0	0	0	0	0	0	0	0
374	45 S	25 W	0	0	0	0	0	0	0	0
375	55 S	25 W	0	0	0	0	0	0	0	0
376	65 S	25 W	0	0	0	0	0	0	0	0
377	75 S	25 W	0	0	0	0	0	0	0	0
378	85 S	25 W	0	0	0	0	0	0	0	0
379	85 N	35 W	0	0	0	0	0	0	0	0
380	75 N	35 W	0	0	0	0	0	0	0	0
381	65 N	35 W	36	14	8	1	0	7	0	66
382	55 N	35 W	0	0	0	0	0	0	0	0
383	45 N	35 W	0	0	0	0	0	0	0	0
384	35 N	35 W	0	0	0	0	0	0	0	0
385	25 N	35 W	0	0	0	0	0	0	0	0
386	15 N	35 W	0	0	0	0	0	0	0	0
387	5 N	35 W	0	0	0	0	0	0	0	0
388	5 S	35 W	291,157	193,836	151,709	2,747	1,115	16,275	3,436	660,273
389	15 S	35 W	97,090	62,417	49,682	1,449	327	4,593	1,092	216,649
390	25 S	35 W	0	0	0	0	0	0	0	0
391	35 S	35 W	0	0	0	0	0	0	0	0
392	45 S	35 W	0	0	0	0	0	0	0	0
393	55 S	35 W	0	0	0	0	0	0	0	0
394	65 S	35 W	0	0	0	0	0	0	0	0
395	75 S	35 W	0	0	0	0	0	0	0	0
396	85 S	35 W	0	0	0	0	0	0	0	0
397	85 N	45 W	0	0	0	0	0	0	0	0
398	75 N	45 W	0	0	0	0	0	0	0	0
399	65 N	45 W	36	14	8	1	0	7	0	66
400	55 N	45 W	0	0	0	0	0	0	0	0
401	45 N	45 W	0	0	0	0	0	0	0	0
402	35 N	45 W	0	0	0	0	0	0	0	0
403	25 N	45 W	0	0	0	0	0	0	0	0
404	15 N	45 W	0	0	0	0	0	0	0	0
405	5 N	45 W	0	0	0	0	0	0	0	0
406	5 S	45 W	69,834	70,450	25,299	726	475	7,180	1,000	174,965
407	15 S	45 W	150,500	189,735	79,611	860	448	7,016	1,510	429,681
408	25 S	45 W	697,510	494,484	387,095	7,319	2,006	27,117	7,764	1,623,298
409	35 S	45 W	0	0	0	0	0	0	0	0
410	45 S	45 W	0	0	0	0	0	0	0	0
411	55 S	45 W	0	0	0	0	0	0	0	0
412	65 S	45 W	0	0	0	0	0	0	0	0
413	75 S	45 W	0	0	0	0	0	0	0	0
414	85 S	45 W	0	0	0	0	0	0	0	0
415	85 N	55 W	0	0	0	0	0	0	0	0

GLOBAL VOC INVENTORY: EMISSIONS IN TONS/YEAR

GRID	LAT	LONG	PARAFFINS	OLEFINS	AROMATICS	FORMALDEHYDE	OTHER ALDEHYDES	OTHER AROMATICS	MARGINALLY REACTIVE	TOTAL VOC
416	75 N	55 W	11	4	2	0	0	2	0	20
417	65 N	55 W	36	14	8	1	0	7	0	66
418	55 N	55 W	17,943	2,275	2,426	321	99	2,001	687	25,753
419	45 N	55 W	2,403	591	525	57	26	586	20	4,208
420	35 N	55 W	0	0	0	0	0	0	0	0
421	25 N	55 W	0	0	0	0	0	0	0	0
422	15 N	55 W	1,672	453	409	57	12	288	15	2,906
423	5 N	55 W	79,989	183,215	1,970	124	65	1,153	88	266,604
424	5 S	55 W	178,540	769,280	29,015	702	138	1,933	549	980,156
425	15 S	55 W	109,308	1,042,696	1,875	186	98	1,698	134	1,156,015
426	25 S	55 W	305,062	256,702	130,978	3,003	711	12,245	1,922	710,624
427	35 S	55 W	342,136	227,972	183,595	4,661	1,179	18,597	3,128	781,268
428	45 S	55 W	0	0	0	0	0	0	0	0
429	55 S	55 W	20	6	5	0	0	5	0	36
430	65 S	55 W	0	0	0	0	0	0	0	0
431	75 S	55 W	0	0	0	0	0	0	0	0
432	85 S	55 W	0	0	0	0	0	0	0	0
433	85 N	65 W	0	0	0	0	0	0	0	0
434	75 N	65 W	11	4	2	0	0	2	0	20
435	65 N	65 W	48	12	10	1	1	12	0	83
436	55 N	65 W	39,447	35,931	919	157	24	315	631	77,423
437	45 N	65 W	140,924	31,084	29,493	3,456	1,406	30,154	1,887	238,404
438	35 N	65 W	481	140	105	9	5	103	5	853
439	25 N	65 W	0	0	0	0	0	0	0	0
440	15 N	65 W	185,860	47,035	30,553	11,785	1,428	25,921	1,210	303,812
441	5 N	65 W	236,304	652,899	17,125	6,907	872	16,178	726	931,012
442	5 S	65 W	108,091	190,960	19,307	616	104	1,335	404	320,618
443	15 S	65 W	101,329	763,375	11,774	498	196	2,799	242	885,212
444	25 S	65 W	31,405	14,208	12,352	926	219	3,543	232	62,944
445	35 S	65 W	93,444	43,651	39,356	2,985	707	10,783	841	196,776
446	45 S	65 W	9,132	3,351	3,389	491	38	505	44	16,949
447	55 S	65 W	15,858	7,494	6,676	747	48	658	55	31,736
448	65 S	65 W	0	0	0	0	0	0	0	0
449	75 S	65 W	0	0	0	0	0	0	0	0
450	85 S	65 W	0	0	0	0	0	0	0	0
451	85 N	75 W	0	0	0	0	0	0	0	0
452	75 N	75 W	0	0	0	0	0	0	0	0
453	65 N	75 W	48	12	10	1	1	12	0	83
454	55 N	75 W	41,587	36,454	1,386	208	47	838	648	81,170
455	45 N	75 W	3,145,649	659,703	635,934	74,055	24,886	435,386	32,384	5,077,798
456	35 N	75 W	937,029	218,107	213,202	13,915	8,824	145,567	23,976	1,565,619
457	25 N	75 W	69,866	34,706	16,185	3,121	465	9,605	454	133,462
458	15 N	75 W	207,454	159,111	63,351	3,596	600	9,301	821	484,234
459	5 N	75 W	354,282	640,819	105,003	5,515	1,568	25,676	1,728	1,134,593
460	5 S	75 W	141,971	130,870	38,941	970	426	6,960	439	320,647
461	15 S	75 W	43,906	30,663	21,479	519	275	3,575	324	101,139
462	25 S	75 W	5,460	3,328	2,369	74	33	578	39	11,762
463	35 S	75 W	95,234	77,159	31,065	1,203	343	5,731	430	211,170
464	45 S	75 W	31,754	36,341	701	21	35	555	36	69,892
465	55 S	75 W	29,662	35,869	268	27	14	256	13	66,049
466	65 S	75 W	0	0	0	0	0	0	0	0
467	75 S	75 W	0	0	0	0	0	0	0	

GLOBAL VOC INVENTORY: EMISSIONS IN TONS/YEAR

GRID	LAT	LONG	PARAFFINS	OLEFINS	AROMATICS	FORMAL-DEHYDE	OTHER ALDEHYDES	OTHER AROMATICS	MARGINALLY REACTIVE	TOTAL VOC
468	85 S	75 W	0	0	0	0	0	0	0	0
469	85 N	85 W	0	0	0	0	0	0	0	0
470	75 N	85 W	0	0	0	0	0	0	0	0
471	65 N	85 W	48	12	10	1	1	12	0	83
472	55 N	85 W	39,970	36,059	1,033	169	30	443	635	78,339
473	45 N	85 W	2,545,678	565,793	521,014	59,639	22,164	390,927	60,979	4,166,184
474	35 N	85 W	1,760,418	439,945	388,005	35,328	16,327	261,661	45,798	2,947,482
475	25 N	85 W	199,611	112,264	46,199	4,024	2,177	39,916	2,734	406,923
476	15 N	85 W	170,204	175,438	71,115	605	209	2,608	349	420,530
477	5 N	85 W	25,539	38,003	14,771	189	65	997	88	79,652
478	5 S	85 W	41,830	19,304	15,548	1,919	103	1,607	116	80,428
479	15 S	85 W	0	0	0	0	0	0	0	0
480	25 S	85 W	0	0	0	0	0	0	0	0
481	35 S	85 W	0	0	0	0	0	0	0	0
482	45 S	85 W	0	0	0	0	0	0	0	0
483	55 S	85 W	0	0	0	0	0	0	0	0
484	65 S	85 W	0	0	0	0	0	0	0	0
485	75 S	85 W	0	0	0	0	0	0	0	0
486	85 S	85 W	0	0	0	0	0	0	0	0
487	85 N	95 W	0	0	0	0	0	0	0	0
488	75 N	95 W	0	0	0	0	0	0	0	0
489	65 N	95 W	238	58	52	6	3	58	2	416
490	55 N	95 W	57,048	37,618	2,806	662	95	1,681	1,298	101,207
491	45 N	95 W	901,499	163,166	165,869	17,074	6,736	118,855	21,452	1,294,651
492	35 N	95 W	1,216,342	265,552	224,785	39,658	10,213	159,873	27,239	1,963,662
493	25 N	95 W	881,267	229,712	132,569	44,269	4,685	69,454	18,172	1,380,129
494	15 N	95 W	499,856	279,722	108,249	7,991	2,221	39,189	11,487	947,716
495	5 N	95 W	0	0	0	0	0	0	0	0
496	5 S	95 W	0	0	0	0	0	0	0	0
497	15 S	95 W	0	0	0	0	0	0	0	0
498	25 S	95 W	0	0	0	0	0	0	0	0
499	35 S	95 W	0	0	0	0	0	0	0	0
500	45 S	95 W	0	0	0	0	0	0	0	0
501	55 S	95 W	0	0	0	0	0	0	0	0
502	65 S	95 W	0	0	0	0	0	0	0	0
503	75 S	95 W	0	0	0	0	0	0	0	0
504	85 S	95 W	0	0	0	0	0	0	0	0
505	85 N	105 W	0	0	0	0	0	0	0	0
506	75 N	105 W	0	0	0	0	0	0	0	0
507	65 N	105 W	238	58	52	6	3	58	2	416
508	55 N	105 W	67,750	42,853	7,103	832	334	7,233	862	126,968
509	45 N	105 W	126,945	27,014	26,083	3,612	1,165	22,657	2,199	209,676
510	35 N	105 W	331,134	57,315	57,737	15,727	2,204	38,957	5,603	508,676
511	25 N	105 W	449,452	343,019	76,510	5,497	2,049	34,000	12,668	925,185
512	15 N	105 W	8,063	2,369	1,720	167	33	1,683	77	14,652
513	5 N	105 W	0	0	0	0	0	0	0	0
514	5 S	105 W	0	0	0	0	0	0	0	0
515	15 S	105 W	0	0	0	0	0	0	0	0
516	25 S	105 W	0	0	0	0	0	0	0	0
517	35 S	105 W	0	0	0	0	0	0	0	0
518	45 S	105 W	0	0	0	0	0	0	0	0
519	55 S	105 W	0	0	0	0	0	0	0	0

GLOBAL VOC INVENTORY: EMISSIONS IN TONS/YEAR

GRID	LAT	LONG	PARAFFINS	OLEFINS	AROMATICS	FORMAL-DEHYDE	OTHER ALDEHYDES	OTHER AROMATICS	MARGINALLY REACTIVE	TOTAL VOC
520	65 S	105 W	0	0	0	0	0	0	0	0
521	75 S	105 W	0	0	0	0	0	0	0	0
522	85 S	105 W	0	0	0	0	0	0	0	0
523	85 N	115 W	0	0	0	0	0	0	0	0
524	75 N	115 W	0	0	0	0	0	0	0	0
525	65 N	115 W	476	116	104	11	5	116	4	833
526	55 N	115 W	356,055	70,881	29,609	7,799	1,574	20,742	14,771	501,429
527	45 N	115 W	97,131	20,389	19,874	2,758	957	20,323	1,165	163,098
528	35 N	115 W	1,145,439	252,488	250,698	29,921	10,377	184,161	24,236	1,897,520
529	25 N	115 W	0	0	0	0	0	0	0	0
530	15 N	115 W	0	0	0	0	0	0	0	0
531	5 N	115 W	0	0	0	0	0	0	0	0
532	5 S	115 W	0	0	0	0	0	0	0	0
533	15 S	115 W	0	0	0	0	0	0	0	0
534	25 S	115 W	0	0	0	0	0	0	0	0
535	35 S	115 W	0	0	0	0	0	0	0	0
536	45 S	115 W	0	0	0	0	0	0	0	0
537	55 S	115 W	0	0	0	0	0	0	0	0
538	65 S	115 W	0	0	0	0	0	0	0	0
539	75 S	115 W	0	0	0	0	0	0	0	0
540	85 S	115 W	0	0	0	0	0	0	0	0
541	85 N	125 W	0	0	0	0	0	0	0	0
542	75 N	125 W	0	0	0	0	0	0	0	0
543	65 N	125 W	476	116	104	11	5	116	4	833
544	55 N	125 W	18,471	1,241	1,469	823	49	849	652	23,955
545	45 N	125 W	583,391	134,162	119,919	11,293	3,654	65,204	17,488	935,112
546	35 N	125 W	619,756	135,123	146,529	14,483	5,450	102,054	13,063	1,036,457
547	25 N	125 W	0	0	0	0	0	0	0	0
548	15 N	125 W	0	0	0	0	0	0	0	0
549	5 N	125 W	0	0	0	0	0	0	0	0
550	5 S	125 W	0	0	0	0	0	0	0	0
551	15 S	125 W	0	0	0	0	0	0	0	0
552	25 S	125 W	0	0	0	0	0	0	0	0
553	35 S	125 W	0	0	0	0	0	0	0	0
554	45 S	125 W	0	0	0	0	0	0	0	0
555	55 S	125 W	0	0	0	0	0	0	0	0
556	65 S	125 W	0	0	0	0	0	0	0	0
557	75 S	125 W	0	0	0	0	0	0	0	0
558	85 S	125 W	0	0	0	0	0	0	0	0
559	85 N	135 W	0	0	0	0	0	0	0	0
560	75 N	135 W	0	0	0	0	0	0	0	0
561	65 N	135 W	476	116	104	11	5	116	4	833
562	55 N	135 W	1,495	335	363	32	14	201	27	2,549
563	45 N	135 W	0	0	0	0	0	0	0	0
564	35 N	135 W	0	0	0	0	0	0	0	0
565	25 N	135 W	0	0	0	0	0	0	0	0
566	15 N	135 W	0	0	0	0	0	0	0	0
567	5 N	135 W	0	0	0	0	0	0	0	0
568	5 S	135 W	0	0	0	0	0	0	0	0
569	15 S	135 W	0	0	0	0	0	0	0	0
570	25 S	135 W	0	0	0	0	0	0	0	0
571	35 S	135 W	0	0	0	0	0	0	0	0

GLOBAL VOC INVENTORY: EMISSIONS IN TONS/YEAR

GRID	LAT	LONG	PARAFFINS	OLEFINS	AROMATICS	FORMALDEHYDE	OTHER ALDEHYDES	OTHER AROMATICS	MARGINALLY REACTIVE	TOTAL VOC
572	45 S	135 W	0	0	0	0	0	0	0	0
573	55 S	135 W	0	0	0	0	0	0	0	0
574	65 S	135 W	0	0	0	0	0	0	0	0
575	75 S	135 W	0	0	0	0	0	0	0	0
576	85 S	135 W	0	0	0	0	0	0	0	0
577	85 N	145 W	0	0	0	0	0	0	0	0
578	75 N	145 W	0	0	0	0	0	0	0	0
579	65 N	145 W	1,312	292	269	42	14	295	10	2,232
580	55 N	145 W	0	0	0	0	0	0	0	0
581	45 N	145 W	0	0	0	0	0	0	0	0
582	35 N	145 W	0	0	0	0	0	0	0	0
583	25 N	145 W	0	0	0	0	0	0	0	0
584	15 N	145 W	0	0	0	0	0	0	0	0
585	5 N	145 W	0	0	0	0	0	0	0	0
586	5 S	145 W	0	0	0	0	0	0	0	0
587	15 S	145 W	1,007	311	293	24	11	203	10	1,859
588	25 S	145 W	0	0	0	0	0	0	0	0
589	35 S	145 W	0	0	0	0	0	0	0	0
590	45 S	145 W	0	0	0	0	0	0	0	0
591	55 S	145 W	0	0	0	0	0	0	0	0
592	65 S	145 W	0	0	0	0	0	0	0	0
593	75 S	145 W	0	0	0	0	0	0	0	0
594	85 S	145 W	0	0	0	0	0	0	0	0
595	85 N	155 W	0	0	0	0	0	0	0	0
596	75 N	155 W	0	0	0	0	0	0	0	0
597	65 N	155 W	964	148	134	59	7	142	5	1,459
598	55 N	155 W	585	139	129	15	7	141	5	1,020
599	45 N	155 W	0	0	0	0	0	0	0	0
600	35 N	155 W	0	0	0	0	0	0	0	0
601	25 N	155 W	3,398	705	650	129	33	708	24	5,648
602	15 N	155 W	0	0	0	0	0	0	0	0
603	5 N	155 W	0	0	0	0	0	0	0	0
604	5 S	155 W	0	0	0	0	0	0	0	0
605	15 S	155 W	0	0	0	0	0	0	0	0
606	25 S	155 W	63	37	13	7	3	11	1	135
607	35 S	155 W	0	0	0	0	0	0	0	0
608	45 S	155 W	0	0	0	0	0	0	0	0
609	55 S	155 W	0	0	0	0	0	0	0	0
610	65 S	155 W	0	0	0	0	0	0	0	0
611	75 S	155 W	0	0	0	0	0	0	0	0
612	85 S	155 W	0	0	0	0	0	0	0	0
613	85 N	165 W	0	0	0	0	0	0	0	0
614	75 N	165 W	0	0	0	0	0	0	0	0
615	65 N	165 W	585	139	129	15	7	141	5	1,020
616	55 N	163 W	0	0	0	0	0	0	0	0
617	45 N	165 W	0	0	0	0	0	0	0	0
618	35 N	165 W	0	0	0	0	0	0	0	0
619	25 N	165 W	0	0	0	0	0	0	0	0
620	15 N	165 W	0	0	0	0	0	0	0	0
621	5 N	165 W	0	0	0	0	0	0	0	0
622	5 S	165 W	0	0	0	0	0	0	0	0
623	15 S	165 W	6	5	1	0	0	0	0	13

GLOBAL VOC INVENTORY: EMISSIONS IN TONS/YEAR

GRID	LAT	LONG	PARAFFINS	OLEFINS	AROMATICS	FORMAL-DEHYDE	OTHER ALDEHYDES	OTHER AROMATICS	MARGINALLY REACTIVE	TOTAL VOC
624	25 S	165 W	0	0	0	0	0	0	0	0
625	35 S	165 W	0	0	0	0	0	0	0	0
626	45 S	165 W	0	0	0	0	0	0	0	0
627	55 S	165 W	0	0	0	0	0	0	0	0
628	65 S	165 W	0	0	0	0	0	0	0	0
629	75 S	165 W	0	0	0	0	0	0	0	0
630	85 S	165 W	0	0	0	0	0	0	0	0
631	85 N	175 W	0	0	0	0	0	0	0	0
632	75 N	175 W	0	0	0	0	0	0	0	0
633	65 N	175 W	0	0	0	0	0	0	0	0
634	55 N	175 W	0	0	0	0	0	0	0	0
635	45 N	175 W	0	0	0	0	0	0	0	0
636	35 N	175 W	0	0	0	0	0	0	0	0
637	25 N	175 W	0	0	0	0	0	0	0	0
638	15 N	175 W	0	0	0	0	0	0	0	0
639	5 N	175 W	0	0	0	0	0	0	0	0
640	5 S	175 W	77	55	13	1	1	7	1	156
641	15 S	175 W	1,219	779	569	49	20	133	9	2,777
642	25 S	175 W	166	101	31	5	2	22	3	332
643	35 S	175 W	0	0	0	0	0	0	0	0
644	45 S	175 W	0	0	0	0	0	0	0	0
645	55 S	175 W	0	0	0	0	0	0	0	0
646	65 S	175 W	0	0	0	0	0	0	0	0
647	75 S	175 W	0	0	0	0	0	0	0	0
648	85 S	175 W	0	0	0	0	0	0	0	0
			55,349,856	42,141,426	15,463,075	1,121,801	338,253	5,138,677	1,002,398	120555686